GEOTECHNICAL MANUAL OF INSTRUCTION

Utah Department of Transportation

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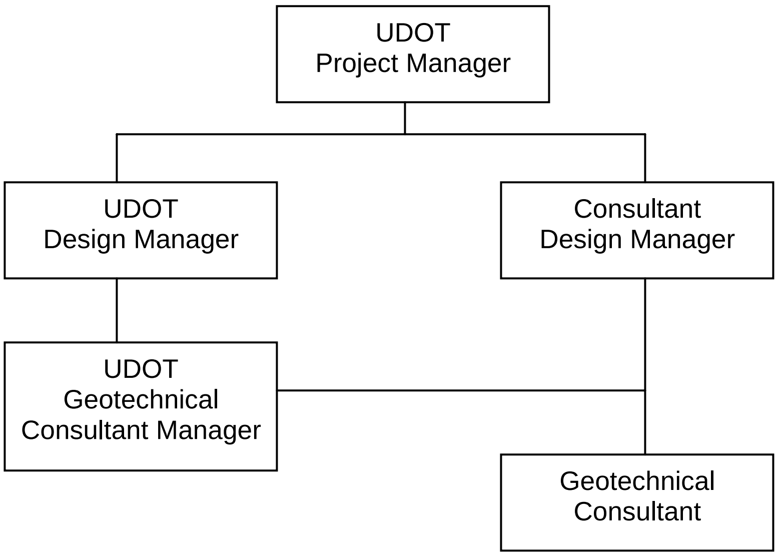
CHAPTER 1: INTRODUCTION

The Geotechnical Manual of Instruction (MOI) has been developed as a guide for both UDOT and consultant design teams. This MOI supplements UDOT's Design process and is meant to provide guidelines for any type of investigation, immaterial of the magnitude and nature of the project. However, this manual is not intended to be all inclusive, therefore one should exercise good engineering judgment in developing an exploration and testing program to assist in developing a comprehensive geotechnical recommendation for the project.

It is recommended that the Geotechnical Division at UDOT headquarters be consulted to clarify any items in the MOI that may not be clear or understood. All geotechnical reports shall be reviewed by a representative of the Geotechnical Division prior to finalizing the findings/recommendations. The ultimate responsibility for the recommendations and/or design will lay with the registered Professional Engineer (Geotechnical) under whose direct supervision the work was performed and who prepared the report.

The preliminary MOI was prepared in early 1999 and is considered to be an evolving document. Any recommendation or critic should be submitted to Geotechnical Division Chief for review and consideration. It is the expectation of UDOT that any or all geotechnical work will be performed in accordance with the MOI. However, if an issue has to be taken to a specific item in the MOI, it shall be done so prior to performing the work and will be provided in writing to the Project Manager for consideration.

CHAPTER 2: GEOTECHNICAL PROJECT MANAGEMENT



CHAPTER 3: SUBSURFACE EXPLORATION1CHAPTER 5: SUBSURFACE EXPLORATION

3.1 GENERAL

Subsurface exploration as outlined here shall mean any type of exploration as a part of an investigation to determine the engineering properties of the subsurface materials. Subsurface exploration shall be conducted at the discretion of the Geotechnical Engineer in consultation with UDOT's Geotechnical Consultant Manager. The FHWA/NHI Subsurface Investigations Manual (1997) and the Standard Recommended Practice for Conducting Geotechnical Subsurface Investigations (AASHTO, 1999) are also good resources for conducting geotechnical investigations for highway projects. The recommendations presented in these references and contained herein are considered to be guidelines; therefore, engineering judgment shall be exercised in developing the exploration program.

Prior to the start of actual field investigations some literature review and preliminary reconnaissance shall be conducted. Available literature including geologic maps, soil surveys, and previous subsurface investigations, as well as field reconnaissance, shall all be utilized to create a useful and cost effective subsurface exploration program.

3.2 LITERATURE REVIEW

3.2.1 U.S. Geological Survey

The major source of geologic maps and information within Utah is the United States Geological Survey (USGS), which has published books, maps, and charts in various forms since 1879. Maps distributed by the USGS include a geologic map of the United States at a scale of 1:24000 and several other series of maps, the best known and most widely used of which are the (1) Folios of the Geologic Atlas of the United States; (2) Geologic Quadrangle Maps of the United States; and (3) Mineral Resources Maps and Charts. The USGS also supplies topographic quadrangle maps of the United States.

3.2.2 Utah Geological Survey and Other Sources of Geologic Information

Geologic information is also available from state and local governmental agencies such as Utah Geological Survey, the Geological Society of America, and the universities.

Also, state, county, and local authorities (planning and zoning) often maintain records of all wells drilled and/or geotechnical/geologic studies within their jurisdiction.

Well logs are available from the Utah Department of Natural Resources, Water Rights Division.

The libraries of local colleges and universities frequently contain detailed geologic information in the form of theses. These libraries are likewise often the source of many out-of-print geologic publications.

3.2.3 Soil Surveys

Soil surveys conducted by various governmental agencies are also a useful source of information for planning of a subsurface exploration program. These surveys, which consist of the mapping of surface and near-surface soils over large areas are of two types namely, agricultural and engineering. ; and are relatively general in nature. This information, published in the form of text and maps, is particularly useful for projects such as highways.

3.2.4 Aerial Photographs

Aerial photographs which are locally available, when reviewed using a stereoscope will provide valuable information on a number of geological features that may not be obvious to the naked eye.

3.3 FIELD RECONNAISSANCE

Subsequent to a review of the available data disclosed by the literature search, and prior to the drilling of exploratory holes, the proposed site shall be inspected by a geologist and/or a geotechnical engineer. The primary objective of the reconnaissance is to obtain as much surface and subsurface information as possible prior to performing subsurface explorations. The types of information to be obtained include accessibility of the site, potential traffic problems, topography, soil profile, surface water and groundwater, erosion patterns, geologic structure, soil deposits, and adverse surface features that could influence the design, construction, and performance of the proposed structure. Soil and bedrock information can be obtained by observation of exposures occurring both naturally and as a result of construction. River banks, natural escarpments, quarries, and highway and railway cuts can provide information about the nature and thickness of soil strata and the bedrock lithology and structure.

3.4 SITE INVESTIGATION PLANNING

3.4.1 General

Site investigation planning shall be done well in advance of any actual exploratory work. It is the responsibility of the Geotechnical Engineer to ensure that all permits/clearances are obtained in time and that all necessary precautions such as evaluation of potential hazards on or around the site etc., are taken ahead of time.

3.4.2 Encroachment Permits (UDOT)

Encroachment permits are required for any type of subsurface exploration/testing located on UDOT property. Contact local UDOT region office for encroachment permit procedures and permits.

3.4.3 Permission to Access Private Property

Permission to access private property must be obtained directly from the property owner. Access shall be requested a minimum of one week prior to initiation of exploration. If verbal authorization is obtained, it shall be documented.

All access to Railroad right of way shall be coordinated with the Engineering Coordinator of Utilities and Railroads.

3.4.4 Required Environmental Clearance and permits

Environmental clearances and permits must be obtained prior to initiating investigations in contaminated areas. Stop drilling if potentially hazardous conditions are identified and contact UDOT’s Risk Management group. Evidence of contamination in any explorations shall be recorded and immediately reported to the region environmental engineer.

3.4.5 Traffic Control Plans (MUTCD)

All exploration sites that require either drilling equipment or personnel to be stationed within 30 feet of a traveled way (interstate, etc.) must have a traffic control plan submitted and approved by Region Traffic and Safety Engineer. Traffic control plans must be submitted at least two weeks prior to the initiation of subsurface investigations.

3.4.6 Utility Clearances (Blue Stakes) and Foundation Check

All exploration sites must be cleared for all known utilities and buried structures prior to the initiation of subsurface exploration. A precise location of all subsurface exploration must be provided to Blue Stakes at 532-5000 (1-800-662-4111) at least 48 hours prior to the initiation of subsurface exploration (it is illegal to perform subsurface investigations in Utah without clearance from Blue Stakes).

For sites with particularly complicated boring locations, Blue Stakes can schedule a site meeting with representatives of subscribing utilities. For subsurface investigations which must be completed within close proximity of utilities, a representative of that utility should be present during subsurface investigations, and hand digging to depths below the utility is recommended. Not all utilities are cleared through Blue Stakes, municipalities and private utilities not cleared through Blue Stakes must be contacted individually.

Note that utility clearances expire after 10 working days.

If UDOT property is damaged or modified in any way due to drilling operations, UDOT maintenance forces must be contacted. Maintenance station personnel are an important source of information and a valuable resource and should be treated as such.

3.4.7 Health and Safety

Any exploration program poses health and safety risks. In addition, drill crews may encounter hazardous subsurface conditions and therefore all drilling should comply with all federal, state, local, and Occupational Safety and Health Administration (OSHA) laws and ordinances. Drilling in such potentially hazardous conditions shall be conducted by trained and certified personnel with the necessary safety gear/equipment.

3.5 SOIL INVESTIGATION

3.5.1 General

The term soil investigation as expressed here shall be considered to include soil borings; test pits; trenches; and in situ testing such as SPT’s, CPT’s, field permeability tests etc. The primary purpose of an investigation program is to provide quality subsurface soil sampling and testing for planning, designing and maintenance of transportation systems.

Soil borings are an essential part of the preliminary engineering investigations for highway bridge foundation design; cut and natural slope stability evaluations; embankment stability evaluations and highway location. The purpose of soil borings are:

- To determine the extent and characteristics of the various natural soil formations
- To obtain representative samples of the different soil formations for laboratory testing
- To investigate possible trouble spots such as springs, swamps, bogs, seepage zones, slide areas, swelling soils, collapsible soils, or any other unusual soil or moisture conditions which could affect construction of highway structures or roadbed stability

All soil boring, sampling, and in situ testing procedures should be completed as specified in this section, in the FHWA/NHI Subsurface Investigations Manual (1997), the relevant ASTM standards, and in the AASHTO Manual on Subsurface Investigations. Where the guidelines presented in this section differ from those given in any of these references, the guidelines of this section should be considered as having precedent. Refer to Appendix A for a comprehensive soil boring exploration check list.

3.5.2 Drilling Procedures

Drilling procedures will vary due to the many different geologic conditions encountered within the State. All of the acceptable drilling procedures are outlined in the AASHTO Manual on Subsurface Investigations. All drilling crews should be familiar with the methods and means as outlined in this manual.

3.5.3 Soil Boring / In Situ Test Frequency and Depth

The following are guidelines for test frequency and depth for borings. Engineering judgment must be exercised in planning and performing subsurface investigations, which shall include consideration for the type and criticality of the project elements, the soil and rock formations, the know variability in stratification, and the loads to be imposed on the foundation materials. In general, soil borings should be extended to the following depths (unless a well defined hard/very dense stratum is encountered above these depths):

- Structures (bridge, building, etc.): generally 1.0 to 2.0 times the width of the structure, but no less than 10 feet below the deepest anticipated pile or caisson tip elevation
- Retaining Walls: 1.0 to 2.0 times the wall height
- Embankments: 2 to 2.5 times the embankment height

In general, the depth of borings will usually be determined by criteria established for design of the element. However, borings for these project elements should not be carried to great depths, unless deemed necessary for deep foundation design or settlement analysis of embankment structures, or for seismic evaluations.

3.5.3.1 Roadway Pavement

As a guideline, soil explorations should be performed every 200 to 500 feet for roadway pavement design. Exploration depth should generally extend to10 feet below the final pavement elevation.

3.5.3.2 Bridges

Exploratory borings (soil and/or rock) shall be located at every bridge abutment and bent (or pier) foundation, unless access conditions at a support will result in excessive exploration costs as determined by the UDOT Project Manager and the Geotechnical Consultant Manager. When the existing subsurface conditions are relatively consistent, the information obtained from one set of borings may be used to interpolate subsurface conditions for the adjacent foundation, with the approval of the Geotechnical Consultant Manager. For bridges with foundation abutment and bents less than 50 feet wide, one boring per abutment or bent should normally be adequate. For bridges greater than 50 feet wide, at least two explorations (one of which may consist of a CPT probe) per location should be considered (to be located at or near opposite ends of each foundation).

3.5.3.3 Retaining Walls (including MSE Walls)

A minimum of one boring should be performed for each retaining wall. For retaining walls more than 100 feet in length, borings should be located generally every 150 to 300 feet. One boring should be located on either side of the roadway if there are walls on both sides; otherwise, locate one boring on the wall-side of the roadway. Refer to approved guidelines for special boring spacing requirements for soil nail walls.

3.5.3.4 Embankments

Borings should be located generally every 200 to 600 feet. One boring should be located on either side of the embankment if there are new embankments on both sides; otherwise, locate one boring beneath the new embankment.

For highway projects, embankment investigations are generally extended to a depth equal to twice the embankment height. Where embankments are underlain by soft soils, the investigation depth will depend primarily on the existing and proposed configuration and shall be evaluated on a case by case basis. Investigations shall be of sufficient extent to provide information on soils that could potentially cause problems with respect to stability and settlements of the embankment.

3.5.3.5 Cut Slopes

At least one boring should be performed for each cut over 15 feet in height. For cuts more than 300 feet in length, borings should be performed generally every 200 to 600 feet (depending on height of cuts and other relevant factors). In general, investigations in cuts should be extended at least 15 feet beyond the anticipated depth of cut and into competent, firm soils or rock. One boring should be located on either side of the embankment if here is a cut slope on both sides; otherwise, locate one boring at the cut section, generally about half way up the cut slope.

3.5.3.6 Buried Structures

Borings shall be located at every major buried structure location. For buried structures less than 50 feet wide, one boring per structure should be adequate. For buried structures greater than 50 feet wide, two borings per structure should be considered.

3.5.3.7 Noise Barriers

Borings should be located generally every 250 to 500 feet along the barrier alignment.

3.5.3.8 Logging of Soil Borings

Soil borings shall be logged in the field and contain information as outlined in Appendix B. This information should be entered into a computer logging program approved by the Geotechnical Division. All information presented on the final logs shall be shown in English units and presented as outlined in Appendix B.

3.6 ROCK BORING/CORING

Rock cores shall be obtained and recovered in accordance with the appropriate sections of the AASHTO Manual on Subsurface Investigations. Rock cores shall be logged in accordance with Appendix E.6 of the AASHTO Manual on Subsurface Investigations and the Code of Stratigraphic Nomenclature. Rock cores shall include RQD data relevant to project requirements (see Appendix D). Oriented cores or downhole digital images may be required, dependent on project requirements.

3.7 TEST PITS/TRENCHES

Backhoe test pits may be used for shallow soil investigations such as for pavement subgrade investigation. Exploratory trenches may be used for fault investigations, collapsible soils identification, etc.

3.7.1 Logging of Test Pits/Trenches

Excavations (test pits and trenches) shall be logged in the field and shall contain information as outlined in Appendix C.

3.8 ABANDONMENT OF EXPLORATIONS

3.8.1 Test Pits / Trenches

Upon completion, the excavation shall be backfilled with the excavated material or other suitable soil material. In cases where any structure, pavement or other flatwork could be located over the excavation, the excavation shall be backfilled with suitable material and compacted in lifts with appropriate compaction equipment as specified in Section 225 of the UDOT Standard Specifications to achieve the necessary compaction. When excavations are outside of any proposed structure, the backfill material shall be tamped in 18-inch lifts to at least 90 percent of standard proctor.

In the case of excavation through existing pavements, the pavement shall be properly patched.

Where excavations are located in agricultural areas or other areas used to support plant growth, the topsoil (or at least the finer upper-layer of the profile) and overburden should be separate from any gravel encountered in the excavation. Upon completion of the excavation, the excavation shall be back filled in such a manner such that the backfilled excavation is left in a condition to support vegetation, as well as or better than what existed originally.

3.8.2 Borings

The UDOT Geotechnical Consultant Manager will determine when and which borings shall be backfilled or grout sealed. Refer to NCHRP (National Cooperative Highway Research Program) Report 378 Recommended Guidelines for Sealing Geotechnical Exploratory Holes. The Driller shall certify that the borings have been properly abandoned in accordance with all applicable guidelines.

3.9 SOIL CLASSIFICATION AND SAMPLING

3.9.1 Field Classification

In general, the approach and format for classifying soils in the field shall conform to ASTM D 2488-93, Visual-Manual Procedure for Description and Identification of Soils.

Some elements of a complete soil description, such as the presence of cobbles or boulders, changes in strata, and the relative proportions of soil types in a layered bedded deposit, shall be obtained in the field. Corrections and additions to the field classification shall be provided, when necessary, by laboratory testing of the soil samples.

Soil descriptions should be precise and comprehensive without being verbose. The correct overall impression of the soil should not be distorted by excessive emphasis on insignificant details. In general, similarities between consecutive samples should be stressed rather than differences.

Soil descriptions shall be recorded in the Soil Description column of the boring log for every soil sample collected. The preferred format and order for soil descriptions is as follows:

- Soil name (synonymous with ASTM D 2488-93 Group Name) with appropriate modifiers
- Group symbol (in bold letters)
- Relative density or consistency
- Moisture Content
- Grain size, soil structure, mineralogy, or other descriptors
- Color

The gradation of coarse-grained soil (more than 50 percent retained on No. 200 sieve) should be included in the specific soil name in accordance with ASTM D 2488-93. There is no need to further document the gradation. However, the maximum size and angularity or roundness of gravel and sand-sized particles should be recorded. For fine grained soil (50 percent or more passing the No. 200 sieve), the name should be modified by the appropriate plasticity term in accordance with ASTM D 2488-93.

Interlayered soil should each be described starting with the predominant type. An introductory name, such as Interlayered Sand and Silt should be used. Also, the relative proportion of each soil type should be indicated.

Where helpful, the evaluation of plasticity can be justified by describing results from any of the visual-manual procedures of identifying fine-grained soils, such as reaction to shaking, toughness of a soil thread, or dry strength as described in ASTM D 2488-93.

3.9.2 Group Symbol

The appropriate group symbol from ASTM D 2488-93 shall be given after each soil name. The group symbol should be placed in parentheses to indicate that the classification has been estimated.

In accordance with ASTM D 2488-93, dual symbols (e.g., GP-GM or SW-SC) may be used to indicate that a soil is estimated to have about 10 percent fines. Borderline symbols (e.g., GM/SM or SW/SP) may be used to indicate that a soil sample has been identified as having properties that do not distinctly place the soil into a specific group. Generally, the group name assigned to a soil with a borderline symbol should be the group name for the first symbol. The use of a borderline symbol shall not be used indiscriminately. Every effort should be made to first place the soil into a single group.

3.9.3 Relative Density or Consistency

Relative density of a coarse-grained (cohesionless) soil is based on N-values (ASTM D 1586-84). Blow-counts presented on the logs shall consist of the raw blow-counts for each 6-inch increment (or refusal); and the corrected $(N_1)_{60}$ values. These values shall be corrected for hammer efficiency, overburden pressure, rod length and sampler diameter.

If the presence of large gravel or disturbance of the samples makes determination of the in situ relative density or consistency difficult, then this item should be left out of the description and explained in the comments column of the soil boring log.

Consistency of fine-grained (cohesive) soil is properly based on results of pocket penetrometer or torvane results. In the absence of this information, consistency may be estimated from N-values. Relationships for determining relative density or consistency of soil samples are given in Tables 3.1 and 3.2 on the following pages.

Table 3.1: Relative Density of Coarse-Grained Soils

$(N_1)_{60}$ (blows/ft)	Relative Density	Field Test
0-4	Very loose	Easily penetrated with ½-inch steel rod pushed by hand
5-10	Loose	Easily penetrated with ½-inch steel rod pushed by hand
11-30	Medium	Easily penetrated with ½-inch rod driven with 5-lb hammer
31-50	Dense	Penetrated a foot with steel rod driven with 5-lb hammer
>50	Very Dense	Penetrated less than 3 inches with steel rod driven with 5-lb hammer

Table 3.2: Consistency of Fine-Grained Soils

$(N_1)_{60}$ (blows/ft)	Consistency	Pocket Penetrometer (kg/cm^2)*	Torvane (kg/cm^2)*	Field Test
<2	Very Soft	<0.25	<0.12	Easily penetrated several centimeters by fist
2-4	Soft	0.25-0.50	0.12-0.25	Easily penetrated several centimeters by thumb
5-8	Firm	0.50-1.0	0.25-0.5	Can be penetrated several centimeters by thumb with moderate effort
9-15	Stiff	1.0-2.0	0.5-1.0	Readily indented by thumb, but penetrated only with great effort
16-30	Very Stiff	2.0-4.0	1.0-2.0	Readily indented with thumbnail
>30	Hard	>4.0	>2.0	Indented with difficulty by thumbnail

** Standard units for instrument*

3.9.4 Moisture Content

The degree of moisture present in a soil sample should be defined in accordance with the following Table 3.3.

Table 3.3: Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Slightly Moist	Apparent moisture but well below optimum moisture content
Moist	Damp, but no visible water; at or near optimum moisture content
Very Moist	Above optimum moisture content
Wet	Visible free water; substantially above optimum moisture content; at or above liquid limit

3.9.5 Soil Structure, Mineralogy, and Other Descriptors

Discontinuities and inclusions are important and shall be described. Such features include joints or fissures, slicken sides, bedding or laminations, veins, root holes, and wood or other debris.

Significant mineralogical information should be noted. Cementation, abundant mica, or unusual mineralogy such as pinhole structure should be described, as well as other information such as organic debris or odor.

Other descriptors can be included if important for the project or for describing the sample. These include particle size, range and percentages, particularly angularity, particle shape, maximum particle size, hardness of large particles, plasticity of fines, dry strength, dilatancy, toughness, reaction to HCL, odor, and cementation.

Residual soils have characteristics of both rock and soil and can be difficult to classify. Relict rock structure should be described and the parent rock identified if possible.

3.9.6 Color

The basic color of a soil, such as brown, gray, or red, must be given. The color term can be modified, if necessary, by adjectives such as light, dark, or mottled. Especially note staining, iron staining, or mottling. This information may be useful to establish water table fluctuations or contamination. As an alternative, the Munsel rock color chart designation may be used.

3.9.7 Laboratory Classification Using USCS System

Laboratory classification of soil using the USCS system shall be used to modify the field descriptions of the soils as appropriate.

3.9.8 Laboratory Classification Using AASHTO System

Soils should be classified according to the AASHTO classification system based upon available laboratory data in accordance with AASHTO M-145. The AASHTO classification letter/number symbol should be shown next to the field (USCS) description on the boring logs.

3.9.9 Sampling

The sampling of soils shall be performed so as to obtain samples which are as representative of subsurface materials as feasibly possible. In general, sampling methods shall follow the FHWA/NHI Subsurface Investigations Manual (1997) and in the AASHTO Manual on Subsurface Investigations.

The sealing of soil samples should be performed as soon as the samples have been exposed and logged (particular promptness is necessary in hot weather conditions). Thin-walled tube samples should be sealed using paraffin wax, o-ring caps, or rubber stoppers. Disturbed samples of soil containing appreciable fines shall be contained in air-tight jars, or in double-bagged sealed plastic bags. Ring and/or liner samples should be wrapped in plastic bags, and then placed and capped in their appropriate containers.

For sites located in areas of either moderate to high seismicity [represented generally as having a maximum horizontal ground acceleration greater than 0.20g for the 2% exceedence in 50 years (USGS/NEHRP, 1996)] and where groundwater is expected in the upper 30-foot strata, soil sampling and laboratory testing shall be performed for liquefaction analysis. As a minimum, SPT soil sampling and $(N_1)_{60}$ determinations for liquefaction evaluation shall be made at a frequency of two every 5 feet in the upper 30 feet of the soil strata. In addition, where liquefaction has been determined to be a concern for a particular site, Cone Penetrometer Test probes (see Section 3.11.1) shall be performed to more specifically assess the liquefaction potential, and to evaluate its effects.

3.10 ROCK CLASSIFICATION

Rock Classification shall be performed with the aid of Code of Stratigraphic Nomenclature and the appropriate section of the AASHTO Manual of Subsurface Investigation, as outlined in Appendix D.
2500.7Rock Classification

3.11 IN SITU TESTING

3.11.1 Cone Penetrometer

The standard Cone Penetrometer Test (CPT) consists of pushing a series of cylindrical rods with a cone at the base into the soil at a constant rate and measuring continuously or at selected depth intervals the penetration resistance of the cone and the friction resistance on a friction sleeve. In addition, the dynamic pore water pressure generated in the soil near the penetrometer tip can be measured during penetration for the piezo-cone CPTU by means of a pore pressure sensor in the penetrometer tip. The scope is limited to soils; the ideal use of the CPT is in areas of known geology with soils being gravelly sands or finer. Various types of sensors can be adapted to cone equipment. Guidelines for various applications and evaluation of CPT's are provided in FHWA Publication No. SA-91-043, February 1992.

The design applications of the standard CPT and piezometric CPTU include: shallow foundation bearing capacity and settlement under vertical or inclined loads, capacities of deep foundations under vertical loads, liquefaction assessments, etc. The Cone Penetrometer Test may be used as a partial replacement for conventional borings. In deposits which will allow for use of a CPT, such as soft clays, the test can be highly valuable when combined with a few traditional soil borings. The CPT provides a continuous record over the depth it is pushed and provides a much better understanding of the layering than would be provided by traditional soil boring.

3.11.2 Logging of CPT's

In general, a computer generated CPT log of soil behavior is provided by the CPT contractor. The CPT log should use English units. Minimum data required for a standard CPT should include tip resistance, sleeve resistance, friction ratio, and soil type interpretation versus depth. Additional information such as pore pressure dissipation and seismic sounding information should be provided on the forms if available.

3.11.3 Shear Strength by Direct Methods

Several devices are available to obtain shear strength data in the field as a supplement to laboratory tests or where it is not possible to obtain representative samples for testing.

Pocket Penetrometer: Used for obtaining the shear strength of cohesive, non-gravelly soils on field exploration or construction sites. The tool should be used as an aid to obtaining uniform classification of soils. **It shall not replace other field tests or laboratory tests.** The value of shear strength given by this test is not necessarily representative of the actual shear strength of the material and shall be used with caution. Multiple tests on an individual sample or sample segment are required with the results reported as an average value.

Torvane Shear Device: Used for obtaining rapid **approximations** of shear strength of cohesive, non-gravelly soils in field exploration. It may be used on the ends of Shelby tubes, penetration samples, and block samples from test pits or the sides of test pits. The device is used in uniform soils and because it only measures a thin section, **it shall also be supplemented by laboratory tests.**

Vane Shear Apparatus: In situ vane shear measurements are useful in very soft soil deposits where much of the strength may be lost by disturbance during sampling. It should be used in stiff clays or in soft soils that do not contain gravel, shells, wood, etc. Procedures for the vane shear test and methods of interpretation are described under ASTM Standard D 2573, Field Vane Shear Test in Cohesive Soil.

Vane shear testing is a useful test in cohesive materials. If performed properly, the test results provide good estimates of in situ undrained strengths for clays and silts.

Field vane test values of undrained shear strength should be corrected to actual undrained strength values using a correction factor developed by Bjerrum (1974).

3.11.4 Deformation Moduli

A number of different methods are available for obtaining values of deformation moduli in soil and rock. Each method has its own advantages or disadvantages and in situ testing should only be attempted with a full knowledge of the limitations of the technique. The pressuremeter may be utilized to assess pile reaction to lateral loads (the pressuremeter is described subsequently).

Pressuremeters: The pressuremeter test shall be conducted in accordance with ASTM D 4719-87. If the test is carried out to failure, shear strengths can be calculated and are generally higher than those obtained from vane shear tests.

The data shall be compared to other tests for verification.

3.11.5 Field Permeability

Many types of field permeability tests can be performed. In situ determination of the hydraulic conductivity of naturally occurring soils can typically be accomplished with a downhole permeability test as outlined in Lambe & Whitman "Soil Mechanics SI Version", John Wiley & Son. The test may be conducted in an open borehole or through a well screen and casing with a defined geometry.

Three different methods can be used in downhole permeability testing: falling, rising, and constant water level methods. In general, either the falling or rising water level methods should be used if the permeability is low enough to permit accurate determination of the water level. In the falling level test, there is a danger of clogging of the soil pores by sediment in the test water used. In the rising level test, there is a danger of the soil at the bottom of the hole becoming loosened or quick if too great a gradient is imposed at the bottom of the hole. Geotechnical boreholes to be used for seepage tests shall be drilled using only clear water as the drilling fluid so as to avoid a mud cake on the walls of the hole.

The horizontal permeability may have a significant influence upon the measurement of hydraulic conductivity in downhole tests. This is especially a problem in inter-bedded materials as are often encountered in lakebed sediments.

A permeability spread of ten or more orders of magnitude has been reported for a number of different types of tests and materials. Measurement of permeability is highly sensitive to both natural and test conditions. The difficulties inherent in field permeability testing require that great care be taken to minimize sources of error and to correctly interpret, and compensate for, deviations from ideal test conditions.

An in situ permeability test in soft to medium stiff clays can also be performed by means of a cone penetrometer equipped with a piezometer. The cone is pushed without a borehole and a falling head permeability test is performed at several predetermined depths. A piezo-profile can thereby be established. The procedures used offer an added advantage in that at each test depth data are obtained which can be interpreted as a falling head permeability test and in situ horizontal permeability values can be computed.

Pressuremeters can also be used to measuring pore dissipation and determine permeability in the field.

3.11.6 Borehole Shear

This test also known as Iowa Borehole Shear Test shall be conducted as outlined in Bowles 1988. The test is applicable for all fine-grained soils and may be performed even where trace gravel is present. It has particular appeal if a good quality borehole can be produced and for modest depths in lieu of undisturbed sample recovery and laboratory testing.

3.11.7 Geophysical Logging

The seismic refraction method is the most predominantly used of the available geophysical methods and is primarily to be used to determine depth of bedrock. Seismic refraction is accomplished by generating seismic waves and measurement of the time required for the waves to travel from the source or sources to a series of geophones (this can also be accomplished with the use of CPT testing).

Cross-hole seismic testing involves using a source or sources in one borehole, and a series of geophones in a second borehole.

Downhole/uphole testing involves using a source and a series of geophones in one hole. These are primarily used to evaluate modules; relative density and resistance to liquefaction.

CHAPTER 4: GEOTECHNICAL TESTING

4.1 INTRODUCTION

The geotechnical testing program shall be conducted at the discretion of the Geotechnical Engineer of Record. Engineering judgment shall be exercised in developing the laboratory testing program. Testing shall be conducted by a accredited laboratory, by trained and certified personnel. The certifications shall be current and maintained through at least the life of the project.

The UDOT Geotechnical Laboratory is located in the Materials Testing Facility (MTF) located directly east of the Calvin Rampton building. The primary function of the laboratory is to provide testing for UDOT's in-house geotechnical design engineers. UDOT 08-1 design process procedure activities 23D, 87D, and 97D are performed by the laboratory.

All initial requests for lab testing on a project and any additional testing that might be needed throughout a project shall be made through the Geotechnical Lab Manager.

4.2 LABORATORY TESTING GUIDELINES

Laboratory soil testing in general should be performed in accordance with the following guidelines:

- Perform laboratory visual identification on all soil samples extracted from the borings.
- Perform moisture content and density analysis on all undisturbed cohesive samples. Atterberg limits tests shall be performed on selected samples in order to provide data for correlation and identification.
- Perform gradation/hydrometer test to characterize grain size for any loose sand deposits greater than 6 feet thick.
- Where consolidation settlement is a concern, perform an adequate number of consolidation tests to determine variation of preconsolidation pressure with depth and variations of compressibility in different strata.
- Perform shear strength tests such as vane shear, unconfined compressive strength test, triaxial shear/direct shear tests in each definable soil deposit, depending on the soil type, purpose and critical nature of structure.
- Perform sulfate content tests at all deep foundation locations.
- Perform resistivity tests to evaluate corrosion effects on metals.
- If sensitive soils are encountered, conduct shear strength tests to determine sensitivity of the soil.
- Refer to guidelines for recommended tests for roadway elements, pavements and structures.

Geomechanical (rock core) testing should be performed in accordance with guidelines set forth in the FHWA/NHI Subsurface Investigations Manual (1997).

4.3 LABORATORY TESTING PROCEDURES

The testing procedures for all of the accredited laboratory soil and rock tests performed are found in AASHTO's Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part II- Tests, and ASTM Vol 4.08 Soil and Rock (I): D420 - D4914. Copies of the latest editions of applicable AASHTO and ASTM testing specifications are maintained in the Geotechnical Laboratory.

4.4 FORMAT OF LABORATORY DATA AND RESULTS

The exact format of the laboratory data and results is not critical as long as all of the required information for a specific test is presented in a neat, concise manner. The QSM contains test records and forms for all of the laboratory tests performed by the UDOT Geotechnical Laboratory. After all laboratory tests are performed, the results should be presented in a format similar to that shown in Appendix E.

4.5 QUALITY ASSURANCE AND QUALITY CONTROL

Laboratory testing shall follow applicable AASHTO/ASTM specifications and in accordance with the Laboratories QA/QC plan or the QSM manual. Samples shall not be tested if they are disturbed, contaminated or otherwise compromised, so as to significantly change laboratory results.

4.6 SAMPLE RETENTION

Soil samples and rock cores should be retained and preserved (to the extent possible) in their original state for a minimum of six months following completion of the investigation or as outlined in the laboratories policies and procedures, whichever is longer. Similarly, laboratory worksheets etc. shall be retained for a period of time for verification purposes, if necessary.

The laboratories policies and procedures shall be presented to the UDOT Geotechnical Consultant Manager so that any changes to these requirements to meet project requirements may be made early in the process and understood by everyone.

4.7 LABORATORY SUBCONTRACTING

If any testing is needed that the consultant's lab is not capable of performing in the required time frame, or does not have the proper equipment to run the test, the work may be subcontracted to an accredited laboratory with the concurrence of the UDOT Geotechnical Consultant Manager. The subcontracted lab shall meet the same contract requirements. However, the Geotechnical Engineer/prime laboratory will ultimately be responsible to UDOT.

CHAPTER 5: GEOTECHNICAL DESIGN

5.1 INTRODUCTION

This geotechnical design section is intended to provide an overview of approved UDOT analysis and design practices. This also provides an overview of available FHWA approved design documents and practices with the intent of maintaining consistency. It is not the intent of this section to provide a step by step procedure for analysis and design. The Geotechnical Engineer is expected to utilize his or her expertise and engineering judgment in carrying out the necessary analysis and design to comply with all of the requirements. The Geotechnical Division encourages that the Division be contacted to review assumptions and approaches to analysis and design procedures.

In order to properly accommodate the guidelines presented herein and/or to incorporate any other project-specific requirements for design or construction, it may be necessary to develop or modify some UDOT standard specifications or drawing details. The Geotechnical Engineer shall ensure that any such items are properly incorporated in special provision specifications and/or the construction drawings.

The current version of the AASHTO LRFD Bridge Design Specifications and any published interims shall be used for all aspects of bridge design with any exceptions directed by the Structures Division or the Chief of the Geotechnical Division.

5.2 RETAINING WALLS

Selection and geotechnical design of retaining walls shall be performed in accordance with the current AASHTO LRFD Standard Specifications for Highway Bridges (or any interims thereof). In addition to the factors of safety described for retaining walls in these AASHTO publications, during construction retaining walls located within the influence of adjacent utilities, buildings or other facilities shall be designed against global instability using a factor of safety of 1.3. Where no adjacent impacts are present, walls shall be designed against global instability during construction using a factor of safety of 1.1. See Section 5.4 and Table 5.1 for further definition of retaining wall design.

Currently, the Department’s following MSE wall special provision specifications are available from the Geotechnical Division:

- 02831S- Retaining Wall- Alternate Systems
- 02832S- Select Backfill for MSE Walls
- 02833S- MSE Walls Using Concrete Facing Panels and Metal Reinforcing Elements

- 02834S- MSE Walls Using Concrete Facing Panels and Geogrid Reinforcing Elements
- 02835S- MSE Walls Using Modular Block Units and Metal Reinforcing Elements
- 02836S- MSE Walls Using Modular Block Units and Geogrid Reinforcing Elements
- 02837S- Two-Stage MSE Walls Using Concrete Facing Panels and Metal Reinforcing Elements
- 02838S- MSE Walls Using Wire Face and Metal Reinforcing Elements
- 02839S- Lightweight Backfill for MSE Walls

Additionally, design of two-stage MSE walls shall conform to FHWA-NHI publication on MSE Walls and Reinforced Soil Slopes, NHI-00-043 (2001). It is recommended that the analysis and design of these systems be reviewed by the Geotechnical Division due to the complexity and empirical nature of these designs.

In accordance with requirements of the current AASHTO Bridge Design Manual, a minimum 4-foot wide horizontal bench shall be provided in front of retaining walls founded on slopes. However, no bench is required where the slope in front of an abutment wall consists of concrete slope paving; a minimum 2-foot depth of cover in front of such abutment walls shall be provided.

5.3 BRIDGE FOUNDATION DESIGN

The current version of the AASHTO Bridge Design Specifications and any published interims shall be used for all aspects of bridge foundation design with any exceptions as directed by the Structures Division or the Chief of the Geotechnical Division.

Bridge foundations are typically spread or deep foundations consisting of piles or drilled shafts. Spread footings are generally not considered acceptable to the Structures or Hydraulics Divisions at stream crossings. An economic analysis should be conducted to determine the optimal foundation system of those technically feasible. Foundation systems deemed unacceptable for support of Department bridges include auger-cast piles, timber piles and Geopiers.

Good communication with the Structures and Hydraulics Divisions is essential to developing a cost effective foundation design. Once the situation and layout plans of the bridge are prepared, a meeting with Hydraulics and Structures is recommended to obtain estimated foundation loads and the scour design information. Follow up with the Structures Division is necessary as the estimated foundation loads can change as the design progresses.

Depending on the method of construction monitoring of the pile installation, various factors of safety (FS) are required for pile design (per AASHTO Bridge Design Specifications).

5.4 SEISMIC POLICY AND PROCEDURES

All bridges shall be designed to meet the 2% exceedence in 50 years (10% in 250 years) hazard level (USGS/NEHRP, 1996), along with all walls located within 50 feet of a bridge foundation and/or that affect the performance or structural integrity of bridges. All other walls shall be designed to meet the 10% in 50-year hazard level (AASHTO, 1996). Embankments need not be designed to a seismic hazard level unless failure will cause significant loss to the bridge and/or to adjacent property or structures; in which case the embankments (including any wrap-around portions of embankments) shall also be designed to meet the 2% exceedence in 50-year hazard level. The acceleration values corresponding to these frequencies shall be obtained from the current NEHRP website (USGS/NEHRP, 1996). Acceptable methods (at this time) for evaluation of embankment/ slope stability during an earthquake are a) pseudo-static method, b) Newmark's displacement method, c) post-earthquake stability method and d) dynamic finite element method.

For the post earthquake analysis, cohesive soils that are not prone to appreciable strength loss during ground motion, a reduction in shear strength of the order of 10 to 20% may be appropriate in the analysis. For soils that are prone to liquefy or that may be severely affected by sustained ground shaking such as sensitive soils, strength parameters used in the analysis should be determined from cyclic triaxial tests where the intensity is governed by the design earthquake. In the absence of cyclic triaxial tests, correlations with residual shear strength may be used.

5.4.1 Liquefaction Hazard Evaluation

Liquefaction hazard evaluation should be performed in accordance with the procedures outlined in Technical Report NCEER-97-0022.

5.4.1.1 Deformation Analysis

Liquefaction problems are generally the result of displacement failures or settlement. Displacement failures can lead to global translation of piles or bridge structures and slump failures of embankments. Liquefaction induced displacement can lead to three types of ground failure (Youd, 1993), flow failure, ground oscillation, and lateral spreading. Flow failures from on steep slopes (greater than 6%) and are characterized by large displacements (tens of feet or more). Ground oscillation occurs on flat ground where liquefaction of deeper layers has decoupled surface soil layers allowing ground oscillations or ground waves to develop. Lateral spreading occurs primarily by horizontal displacement

of superficial soil layers due to liquefaction of underlying granular deposits. Lateral spreads move down gentle slopes (usually less than 6%) or slide towards a free face such as a road cut or incised river channel. Horizontal displacements may range from a few inches to several feet.
Empirical procedures provided by Bartlett, Youd and Hansen (1992 and 2002) shall be followed to assess the conditions and magnitude of lateral spreading. The level of risk associated with lateral spreading should also consider the geologic and topographic conditions at, and for the surrounding vicinity of the site.

Settlement occurs when liquefaction and attendant pore pressure dissipation causes densification of the liquefied layer. The magnitude of settlement (volumetric strain) under flat topographic conditions can be determined from charts developed by Tokimatsu and Seed (1987) based on the average cyclic shear stress ratio induced by the earthquake and the $(N_1)_{60}$ value of the soil in question. The magnitude of settlement may result in damage to overlying structures or introduction of negative skin friction on pile foundations due to settlement of liquefiable layers underlying cohesive soils. The potential effects of negative skin friction should be evaluated in pile design.

Pile design should also include an assessment of capacity reduction due to a decrease in strength of soils under seismic loading. For liquefiable layers, residual strengths should be used in determining, vertical, uplift and lateral pile capacities under seismic loading condition. Selection of appropriate residual strengths based on equivalent clean sand SPT blow-counts in undrained conditions as outlined in Seed and Harder (1990), shall be followed. The average value of the band is recommended for use in pile design.

If the factor of safety (FS) against liquefaction is less than 1.1 for soils underlying retaining walls or embankments located adjacent to bridge foundations additional analyses shall include post-earthquake conditions. Thus, residual strength values shall be used that reflect a liquefied state; however, a lateral earthquake force shall not be used in the post-earthquake analysis. For a post-earthquake analysis, the average residual strength shall be used for liquefiable materials. Depending on the FS determined from the post-earthquake analysis, the following are recommended:

- If FS> 1.1, no additional earthquake analyses are required.
- If FS< 1.1 a deformation analysis shall be performed using either Newmark method or the Makdisi-Seed (1977) simplification of the Newmark method to evaluate the magnitude of permanent embankment deformation. If deformation exceeds acceptable magnitudes measures or configuration alteration shall be evaluated that result in acceptable deformation magnitudes.

It has recently been determined that using accelerations greater than about 0.3g in conventional pseudo-static design methodology, is no longer considered to be the most appropriate approach. Therefore, as an alternative to pseudo-static design methods, where peak ground acceleration values exceed 0.29 g, a detailed lateral deformation analysis (such as the Newmark method) should be performed using the acceleration value(s) determined for the site (see first paragraph of this section).

5.5 EMBANKMENT STABILITY AND SETTLEMENT DESIGN

All new highway embankment fills or widening of existing fills (sliver fills) shall be evaluated for stability, settlement and other conditions as warranted. Magnitude and time rate of settlement shall both be evaluated. Evaluation and design of embankments shall be performed using accepted methodology, including the use of two-dimensional slope stability computer software programs such as XSTABL, STABL5M, STABL6 or UTEXAS. For highway embankments located within 50 feet of a bridge foundation and/or that affect the performance or structural integrity of bridges; or are within the influence zone of adjacent utilities, buildings or other facilities, use a minimum factor of safety for long-term global stability of 1.3 for static conditions and 1.0 for pseudo-static conditions. All other embankments shall be designed for global stability static conditions using a minimum factor of safety of 1.2; and no pseudo-static analysis need be performed. During construction, highway embankments located within the influence zone of adjacent utilities, buildings or other facilities, shall be designed against global instability using a factor of safety of 1.3. Where no adjacent impacts are present, embankments shall be designed against global instability during construction using a FS of 1.1. These design factors of safety are summarized in Table 5.1.

Where the subgrade beneath proposed embankments includes fine grained soils (other than very stiff to hard deposits), the embankments shall be analyzed for overall bearing capacity (edge bearing shall also be checked where appropriate). Where adjacent impacts are present as described above, a minimum factor of safety of 2.0 shall be used for overall bearing capacity; where no adjacent impacts are present, a minimum value of 1.5 shall be used. For medium stiff to very soft fine grained soils, lateral spreading and lateral squeezing shall also be examined (see FHWA, Soil Slope & Embankment Design, 2002). Minimum required factors of safety for these conditions are also presented in Table 5.1.

If minimum factors of safety are not achieved during design analysis, slopes may need to be flattened, subgrade improved, embankment slopes reinforced (such as with high-strength geotextiles), or some sort of staged-construction implemented. If subgrade stability is marginal, piezometers shall be installed and conscientiously monitored so that embankment construction can be halted and/or fill removed if excess pore water pressures become excessive. Factors of safety against stability should be improved where necessary with the use of geotextiles, geogrid or other appropriate measures.

All embankments should be evaluated for short term (primary consolidation) and long term (secondary consolidation) settlement conditions. If either magnitude (adversely affecting utilities, adjacent structures, etc.) or time rate of settlement (affecting construction schedule, etc.) are concerns, alternative methods of accelerating time rate of settlement or reducing magnitude of settlement such as, use of wick drains in conjunction with surcharge; use of lightweight fills; or stone columns/lime cement columns to stabilize subgrade soils etc. shall be evaluated. Such evaluations (as a minimum) shall follow established and acceptable guidelines. The Geotechnical Division shall be contacted to review the proposed methods to mitigate such conditions.

5.6 SUMMARY OF DESIGN FACTORS OF SAFETY

A summary of appropriate design factors of safety for retaining walls and embankments as described by AASHTO (AASHTO, 1996) and the Department (this section) is presented in Table 5.1.

Table 5.1: Summary of Minimum Allowable Factors of Safety
Embankments and Retaining Wall Stability

		Condition	UDOT	AASHTO
Embankments Adjacent to Abutments*	Construction Global Stability	Static (Non-Impact)	1.1	
		Static (Adjacent Impact)	1.3	
	Long-Term Global Stability	Static	1.3	
		Dynamic (10% PE 250 yrs)	1.0	
		Post-Liquefaction Analysis	**	
	Overall Bearing Capacity	Static	2.0	
	Lateral Spreading	Static	2.0	
	Lateral Squeezing	Static	1.5	
Walls Adjacent to Abutments*	Construction Global Stability	Static (Non-Impact)	1.1	
		Static (Adjacent Impact)	1.3	
	Long-Term Global Stability	Static		1.5
		Dynamic (10% PE 250 yrs)	1.0	1.1
		Post-Liquefaction Analysis	**	---
	Sliding	Static		1.5
	Overturning	Static		2.0
	Bearing	Static		2.5
General Embankments	Construction Global Stability	Static (Non-Impact)	1.1	
		Static (Adjacent Impact)	1.3	
	Long-Term Global Stability	Static	1.2	
		Dynamic	N/R***	
	Overall Bearing Capacity	Static	1.5	
	Lateral Spreading	Static	1.5	
	Lateral Squeezing	Static	1.3	
General Walls	Construction Global Stability	Static (Non-Impact)	1.1	
		Static (Adjacent Impact)	1.3	
	Long-Term Global Stability	Static		1.3
		Dynamic (10% PE 50 yrs)	1.0	1.1
		Post-Liquefaction Analysis	**	–-
	Sliding	Static		1.5
	Overturning	Static		2.0
	Bearing	Static		2.5

** Within 50 feet of the foundation*
*** Post-Liquefaction Deformation Analysis required where FS < 1.1 for the designated seismic acceleration (See Section 5.4.1.1)*
**** N/R- Not required*

5.7 FILL AND OTHER GEOTECHNICAL MATERIALS

The requirements for fill materials used for Department projects are presented in the UDOT Standard Specifications. Section 02056- Common Fill indicates that Borrow consists of AASHTO soil classifications A-1 through A-4. It is recognized however that the use of A-4 silt/sandy silt as pavement subbase (i.e. the upper portion of embankment material beneath roadways) will increase the potential for trapping water in the pavement subgrade, induce a greater potential for capillary rise of moisture, and provide a lesser quality of subgrade support (particularly for long-term pavement performance). Therefore, when the bottom of the pavement section (Granular Borrow or subbase) is to be located within 5 feet of the annual high groundwater level, imported material and/or roadway excavation containing more than 50 percent fines should not be allowed in the final 3-foot zone of embankment material placed below the pavement section. In all other cases, no material containing more than 50 percent fines should be allowed in the final 1-foot zone of embankment material below the pavement section. These requirements should be incorporated by Embankment special provision where necessary.

Additionally, Section 02330- Embankment describes the use of excavated materials in embankments without specified exclusions. However, it is recognized that the use of moderately to highly plastic clay, problematic shale, certain volcanics, and other deleterious excavated materials can result in unacceptable long-term performance of embankments. Such excavated materials should therefore be excluded from use as embankment material, by incorporating an Embankment special provision specification where necessary.

Other geotechnical materials acceptable by the Department for use on Department projects include wick drains, composite drains, horizontal drains/sand drains, and lightweight materials/fills. Acceptable lightweight materials include expanded polystyrene (such as Geofoam), expanded shale/ceramic aggregate, foamed concrete (such as Elastizell and Northeastern Soltite), and scoria. Special provision specifications are currently available from the Geotechnical Division for Geofoam, scoria, and steel slag lightweight aggregates. Written permission from the Department is be required in order to allow the use of broken concrete in fills. The use of shredded tires, fly ash, bottom ash, or wood fibers in fills is not allowed.

5.8 CUT SLOPE DESIGN

Design of cut slopes can be complicated based on the geology, subsurface materials and surface conditions. Added to the complexity may be the limitation on obtaining engineering properties of these materials and therefore the Geotechnical Engineer may have to draw on the local area experience. As a rule of thumb, slopes steeper than 2.5H:1V should be eliminated where ever possible. If steeper slopes cannot be avoided use methods as outlined in TRB Special Report 247 “Landslides Investigation and Mitigation” or “Slope Stability and Stabilization Methods” by Abramson, L.W., Lee, T.S., Sharma, S., and Boyce, G.M., 1995; or “Stability Analysis of Earth Slopes” by Yang H. Huang as a basis for analysis and design. Cut slope design shall include evaluations for both static and dynamic conditions; and evaluations for rockfall considerations. Rockfall evaluation shall include both acceptable simulation programs (such as CRSP-Colorado Rockfall Simulation Program) and the Ritchie Ditch criteria (TRB Special Report 247, Figure 18-15). The Geotechnical Division will verify the appropriate factors of safety for cut slope design to be considered for each project.

5.9 GEOLOGIC REPORT GUIDELINES

Geologic reports shall be prepared by a Professional Geologist licensed in the State of Utah with a minimum of 5 years of experience in similar type of work and reports shall be as outlined on Appendix F.

CHAPTER 6: CONSTRUCTION PHASE SERVICES

6.1 INTRODUCTION

Construction phase services may be required of the Geotechnical Engineer to:

- Ensure compliance with geotechnical recommendations
- Develop and implement an instrumentation program
- Perform static pile load test
- Evaluate existing conditions and revise recommendations, if necessary
- Evaluate pile capacities use PDA
- Provide clarification for the recommendations and/or specifications

All of the above services shall be provided (if necessary) and under the direct supervision of the Geotechnical Engineer and in accordance with applicable standards.

6.2 RECORD KEEPING

Geotechnical Engineer shall maintain a thorough log of all field visits, and observations/ recommendations made during the field visit. If any changes to the original design are made in the filed, the necessary documentation to substantiate such changes shall be presented to the Geotechnical Consultant Manager for review and concurrence. No changes shall be made without the concurrence of the UDOT Project Manager.

6.3 PILE DRIVING ANALYZER

Piles capacities shall be evaluated at every new bridge abutment and bent locations (at least one pile per location) using a Pile Driving Analyzer (PDA). The capacities shall be evaluated both during initial driving and during restrike of the same pile. The evaluation shall be done in accordance with UDOT Standard Specification 02455 and other applicable standards such as ASTM 4945, using approved equipment. Case Pile Wave Analysis Program (CAPWAP) analysis shall be used to evaluate the PDA data at each abutment or bent location. PDA is routinely performed by the Geotechnical Division. In the event the Geotechnical Division cannot perform PDA, the evaluation shall be conducted by a pre-qualified consultant in accordance with the approved scope of work. The scope of work shall include a QA/QC plan. Any changes to the capacity etc., shall be reviewed by the UDOT Geotechnical Consultant Manager and approved.

6.4 DEEP FOUNDATION STATIC LOAD TESTS

Static load tests (if required) shall be performed in accordance with ASTM D-1143 using the quick load method. An economic analysis should be performed during design of the deep foundation to determine the cost benefit of a static load test utilizing the required factors of safety as recommended in the AASHTO Bridge Design manual.

Through arrangements with the Civil Engineering Department of Brigham Young University (BYU), a pile load test frame is to made available for use on UDOT projects. The load frame is located at a BYU storage facility. The Designer or Contractor will be required to make the necessary arrangements with Kyle Rollins at BYU (801-378-6334) to schedule use of the load frame at least 60 days in advance. The load frame will be considered properly scheduled when BYU receives a bond for $30,000 for use of the load frame. Failure to return the load frame and all of its components to the designated BYU storage facility in at least the same condition as when the frame was borrowed and/or with in 15 days as scheduled, will result in forfeiture of the bond amount. All loading, transportation, and handling of the load frame will be the responsibility of the Designer or Contractor.

Interpretation of the static load test should be performed utilizing the Davisson's offset limit as directed in the DFI manual Guidelines for the Interpretation and Analysis of the static Loading Test. Additional pile load test information may be obtained from the following FHWA manuals:

- Manual on Design and Const. of Driven Pile Foundation FHWA-DP-66-1
- Design and Construction of Driven Pile Foundations NHI Course 13221 and 13222

6.5 INSPECTION OF DRILLED SHAFTS AND AUGERED C.I.P. PILES

Drilled shafts and augered cast-in-place (C.I.P.) piles shall be inspected by a representative of the Geotechnical Engineer. The following manuals provided by ASFE, ADSC and DFI are available to use as guides for inspection:

- Augered C.I.P. Piles Manual
- Inspectors Guide to Augered C.I.P. Piles
- Drilled Shaft Inspectors Manual
- Recommended Procedures for the Entry of Drilled Shaft Foundation Excavations

Information on inspection of drilled shaft foundations is also provided in the following FHWA Manuals:

- Drilled Shafts for Bridge Foundations FHWA-RD-92-004
- Bored Piles FHWA-TS-86-206

6.6 VIBRATION MONITORING

The UDOT Geotechnical Division maintains ground vibration monitoring equipment for the purpose of assessment of vibration at properties potentially impacted by roadway blasting, construction equipment and compaction traffic. Vibration equipment and personal are available on an as-needed basis as conditions warrants. If UDOT personnel or equipment are currently in use or unavailable, the Project Team will be required to make arrangements for a firm independent of the Contractor to perform vibration monitoring as needed.

6.7 OTHER INSTRUMENTATION

Where deemed appropriate by the Consultant and/or the Department, other geotechnical instrumentation shall be provided. The instrumentation program shall be outlined in sufficient detail and submitted to the Geotechnical Division for review, prior to beginning installation of the instruments. Where settlement of high embankments are a consideration, long-term settlement instrumentation arrays should be provided in secure locations.

In-place surface and subsurface field instrumentation shall include sturdy lockable protective covers. A special provision specification should be provided where necessary, to require the Contractor to provide full payment for replacement of any instrumentation damaged during construction.

CHAPTER 7: LOCAL GOVERNMENT PROJECTS

CHAPTER 8: MAINTENANCE SUPPORT

8.1 DESCRIPTION

The Geotechnical Division will provide the needed services to UDOT's maintenance group for the following situations.

- Landslides
- Rockfalls
- Other Geotechnical related issues

Geotechnical consultants may occasionally be retained to assist the Geotechnical Division in specialized situations. The services will be provided in accordance with applicable procedures and standards.

APPENDIX A: GENERAL FIELD WORK FORMS

EXAMPLE FIELD RECONNAISSANCE REPORT FORM

BRIDGE FOUNDATION OR OTHER DRILLING SITE
GEOTECHNICAL DIVISION
UTAH DEPARTMENT OF TRANSPORTATION

PROJECT NO.:_______________ COUNTY: ___________________ STA. NO.: _____________
REPORTED BY:_____________________________ DATE ______________________________

1. STAKING OF LINE
   ____Well Staked
   ____Poorly Staked, Can we still use? ____
   ____Request Division to Restake

2. BENCH MARKS
   In Place: Yes _____ No _____
   Distance from Bridge __ (ft/m)

3. PROPERTY OWNERS
   Granted Permission: Yes _____ No _____
   Remarks On Back ____________________

4. UTILITIES
   Will Drillers Encounter Underground or Overhead
   Utilities: Yes ____ No _____ Maybe ____
   At Which Holes? ____________
   What Type? ________________
   Who to See for Definite Location __________
   ____

5. GEOLOGIC FORMATION _______________
   ____

6. SURFACE SOILS
   Sand ___ Clay ___ Sandy Clay/Clayey Sand
   Rock _____ Silt _____ Other _______________

7. GENERAL SITE DESCRIPTION
   Topography
   Level _____ Rolling _____ Hillside _____
   Valley _____ Swamp _____ Guillied _____
   Groundcover:
   Cleared _____ Farmed _____ Buildings ____
   Heavy Woods _____ Light Woods _____

8. BRIDGE SITE
   Replacing _________________________
   Widening __________________________
   Relocation _________________________
   Check Appropriate Equipment
   _____ Truck Mounted Drill Rig
   _____ Track Mounted Drill Rig
   _____ Failing 1500
   _____ Truck Mounted Skid Rig
   _____ Skid Rig
   _____ Rock Coring Rig

8. BRIDGE SITE - Cont'd
   ____ Wash Boring Equipment
   ____ Water Wagon
   ____ Pump
   ____ Hose (ft/m)
   Cut Section ___ (ft/m)
   Fill Section _ (ft/m)
   If Stream Crossing:
   Will Pontoons Be Necessary? ______
   Can Pontoons Be Placed In Water Easily?
   ____
   Can Cable Be Stretched Across Stream?
   ____ How Long? ______ (ft/m)
   Is Outboard Motorboat Necessary? _____
   Current:
   Swift: ___ Moderate: ___ Slow: ____
   Describe Streambanks Scour:
   If Present Bridge Nearby:
   Type of Foundation_____________
   ____
   Any Problems Evident in Old Bridge?
   (Incl scour):_____________________
   if nec, describe on back
   Is Water Nearby for Wet Drilling? Dis: __ (ft/m)

9. GROUNDWATER TABLE
   Close to Surface _______________ (ft/m)
   Nearby Wells ______ ___________ (ft/m)
   Intermediate Depth __________(ft/m)

10. ROCK
   Boulders Over Area? Yes _____ No _____
   Definite Outcrop? Yes _____ No _____
   (show sketch on back)

11. SPECIAL EQUIPMENT NECESSARY
   ____
   ____

12. REMARKS ON ACCESS (describe any potential problems with access)
   ____
   ____

13. DEBRIS AND SANITARY DUMPS
   Stations _________________________
   Remarks ________________________

Reference: 1978 AASHTO Foundation Investigation Manual

PERMIT TO ENTER AND CONDUCT EXPLORATORY DRILLING

Job. No.: ________________ Address (attach map): ______________________

Incident to the "project description", ________________________ hereinafter referred to as " ____________________", and the owner of the property at the above indicated address, hereinafter referred to as "OWNER", do agree as follows:

The OWNER hereby authorizes ______________________ or its agent or contractor, to enter and conduct exploratory drilling on the property; install inclinometer casing and/or water observation wells; and to occasionally enter the property on an as-needed basis to conduct downhole monitoring.

The OWNER hereby certifies that he/she is the OWNER of the property at the address indicated above.

This permit shall expire at the completion of the project or two years from the date of signing of this permit, or by revocation by OWNER in writing.

The foregoing covenants in each and every particular are and shall be construed as real covenants and shall run with the land, and the same hereby made binding upon the heirs, administrators, executors, devisees, assigns and successors in interest of the parties hereto.

Geotechnical Consultant: _____________________________

By: ______________________________ ______________________________

Project Manager Date Owner Date

JOB SITE FORM

Project Name ________________________________ Project No. ______________________
Drilling Site Location ____
County ________________ Date Inspected ________________ Geologist ________________
Driller __________________

ELECTRIC POWER COMPANY:
Name of Co. ____
Date Contacted _____________________________ Person Contacted __________________
Location Aerial Lines ____
Location Buried Lines ____
FUEL COMPANY:
Name of Co. ____
Date Contacted _____________________________ Person Contacted __________________
Location Buried Lines ____
PHONE COMPANY:
Name of Co. ____
Date Contacted _____________________________ Person Contacted __________________
Location Aerial Lines ____
Location Buried Lines ____
WATER & SEWER COMPANY:
Name of Co.
Date Contacted Person Contacted
Location Buried Lines
OTHER UTILITIES; RAILROADS:
Name of Co. ____
Date Contacted _____________________________ Person Contacted __________________
Location Buried Lines ____
Owners Name ____
Address ____ Phone __________________
Special Provisions____
Remarks ____
Owners Name ____
Address ____ Phone __________________
Special Provisions____
Remarks ____
Owners Name ____
Address ____ Phone __________________
Special Provisions____
Remarks ____

Sketch Map

ON SITE VISUAL INSPECTION

Geo. Driller
1. ___|___ Overhead power of telephone line-
Minimum 10 ft. clearance
2. ___|___ Buried cable markers, power, telephone.
3. ___|___ Buried gas line markers.

APPENDIX B: EXPLORATION LOG GUIDELINES

The following information is required for both field and final exploration logs (borings and test pits), unless otherwise specified:

1. Project name
2. Project location
3. UDOT project number
4. Location of borehole or test pit. Where UDOT stationing is available, describe the position of the exploration with respect to the stationing, including the offset (left or right) from centerline. Where useful, a sketch of the exploration position should also be provided on the field boring log. Where stationing is not available, locations should be accurately determined by tape or survey, and should be recorded on each exploration.
5. Start date and time of exploration.
6. Completed date and time of exploration.
7. Weather: Enter the approximate ambient conditions, i.e. temperature, wind and amount/type of precipitation at the time of exploration.
8. Exploration number. Numbering should be in accordance with UDOT guidelines. Where explorations are performed for subsequent phases, use letters or +100 numbering so as to distinguish (i.e. B-R1, B-R2…or B-101, B102…)
9. Borehole inclination
10. Sheet ___ of ___ numbers
11. Names of geotechnical firm
12. Name of field engineer/geologist
13. Name of drilling contractor/backhoe company, together with their city and state where based.
14. Name of driller and driller’s helper, or backhoe operator
15. Method of drilling
    - Wash: rotary, air, cable tool
    - Auger (including diameter): flight, hollow-stem, bucket
    - Air hammer
16. Drilling fluid: bentonite, Revert, polymer or none
17. Make of drilling equipment
18. Drill model number
19. Surface elevation. Measure the ground surface elevation of the exploration using a surveyor’s level or as a minimum by hand-level. Record the elevation on each exploration log.
20. Borehole diameter.
21. Drill bit type and size
22. Inside diameter of casing
23. Casing wall thickness
24. Cased depth
25. Excavation Method and Equipment: Identify the mode and make (John Deere,

Case, etc.) of backhoe or other excavator, together with the bucket width.

26. Depth scale
27. Sampling depths
28. Methods of sampling (pushing, hammering, drilling, coring)
29. Sampler (Shelby tube, SPT, Modified California, Dames & Moore, Pitcher barrel, Osterberg, Sprange & Henwood, hand carved, etc.)
30. Blow counts
31. Sample number
32. Depth of changed ground/drilling conditions
33. Soil information (description, ASTM classification, USCS symbol, color, density or consistency/hardness, moisture, minor constituents, etc.)
34. Depth of exploration termination
35. Laboratory index test data results
36. Recovery
37. Remarks
38. Backfilling information
39. Abandonment procedures
40. Abandonment certification
41. Field testing (pocket penetrometer, field vane, torvane, falling head permeability)
42. Depth of wells/piezometers
43. Piezometer screen interval
44. Groundwater levels: during exploration, subsequent to completion, and after installation of well (see notes on following page)
45. Signs of contamination
46. Type of contamination
47. Contamination measurements

Additional information which shall be shown in the final logs is as follows:

- Depth below surface: use a depth scale on the boring log that is suitable to the planned depth of exploratory boring (1"=3" is the preferred scale)
- Sample interval: clearly indicate the top and bottom depth of the range of sampler penetration. Also indicate whether the sample is disturbed or undisturbed. Enter the depth range of the sample interval and the amount of recovery.
- Sample type and number: enter the sample type (i.e., SPT, type-U, etc.) and number. Number samples consecutively regardless of type. Enter a sample number, even if no sample was recovered.
- Sample recovery: enter the length to the nearest inch of soil sample recovered from the sampler. Do not include slough in the sample.
- Penetration test results: In this column enter the number of blows required for each 6 inches of sampler penetration and the N value, which is the sum of the blows in the last two 6-inch penetration intervals. A typical standard penetration test involving successive blow counts of 3, 4, and 5 is recorded as 3-4-5 and 9 (circle the 9) The standard penetration test is terminated if the

sample encounters practical refusal. Practical refusal should be considered as a blow count of 50 for an interval less than 6 inches. A partial penetration, for example of 50 blows for 1 inch, is recorded as 50/1". Also enter the size, type, and section length of the sampling rods. See the Standard Penetration Test Procedures subsection for additional discussion. Penetration test should be normalized for difference from standard equipment and procedures prior to being entered into final logs. If an non-standard penetration test was used, the blow-counts should be converted to SPT blow-count and entered in final logs with an asterisk denoting that the blow-count was converted from a non-standard blow-count. Also record the hammer weight, type, drop interval, and non-standard sampler dimensions.

- Soil Description: The soil classification should follow the USCS format. The AASHTO letter/number designation should be shown next to the USCS description. Where appropriate laboratory tests have been performed, the Geotechnical Engineer will be responsible to assign the equivalent AASHTO soil designations and present them in parentheses on the final logs.
- Groundwater: Enter the depth below ground surface to the static groundwater level in the exploration if encountered. When groundwater is encountered, borings shall be left open for however long possible to monitor groundwater elevations. Generally, groundwater levels should be measured each morning before resuming drilling and at the completion of each boring. If free groundwater is not encountered during drilling, or cannot be detected because of the drilling method, this information should not be noted. Record the date and time of day of each groundwater level measurement in the field log.
- Comments: Include all pertinent observations (changes in drilling fluid color or loss, rod drops, drilling chatter, rod bounce as in driving on cobble, easy advancement of hollow stem augers, damaged samplers, and equipment malfunctions) in the field log. Also note if rock coring was used at any point to advance the boring through cobbles, boulders, etc. The Driller should be instructed to report any significant changes during drilling (changes in material, occurrence of boulders, and loss of drilling fluid).

APPENDIX C: TEST PIT / TRENCH SAMPLING

Sufficient amounts of representative material shall be collected from the test pit for the intended laboratory observation and testing. If the desired types of testing is unknown, additional material shall be taken than would normally be anticipated.

If samples are required from a specific part of the test pits, do not accept a sample that has been raked up through the overburden and topsoil.

Excluding bulk samples, to prevent moisture loss, the samples shall be well-sealed using either plastic bags, jars, and/or taped plastic containers. The samples shall be properly and clearly labeled by recording both the depth and sample number (see below), as well as on the test pit log.

It is suggested that undisturbed samples be carefully collected by pushing brass rings of the U-type (sometimes referred to as the California sampler. These rings have an OD of 2.50 inches (63.5 mm) and an ID of 2.42 inches (61.5 mm). Ring heights of 1.00 inch (25.4 mm) and 3.0 inches (76 mm) are used by the Geotechnical Division (with the latter found to be particularly desirable for collapse tests); and 6.0-inch (152-mm) long liners can also be obtained, particularly where unconfined compression testing is desired.

In some instances such as for potentially collapsible soil, it is advantageous to collect block samples of porous soils from test pits. Block samples should be carefully handled and transported to the laboratory so as to preserve their integrity.

General information for preparing logs of exploratory test pits / trenches are as follows:

Depth Below Surface: Use a depth scale on the test pit log that is suitable to the planned depth of the test pit.

Sample Type, Number and Depth: Enter the sample type (i.e., U-type, bag, bulk, etc.), number and depth. Number samples consecutively regardless of type. Clearly indicate the top and bottom depth of the range of the collected sample.

Soil Description: The soil classification should follow the USCS format described in ASTM 2488. Where laboratory classification testing has been performed, the AASHTO letter/number designation should be shown next to the USCS description.

Information to be noted on the logs should also include:

- Lenses or layers of gravel, pea gravel, sand, silt or clay (either in the form of clay balls or clay lenses). This would also include isolated pockets of sand, silt, or clay.
- If measurable amount of soft sedimentary rock, clay, and silt balls elongated or flat particles are observed, the fact should be recorded and estimated as a percentage on the logs.
- If groundwater is encountered, indictment should indicate the distance below ground level and whether water flows or seeps into the test hole.
- Any observed variations, measure and sketch on the log where necessary. Every effort must be made to ensure that samples are not contaminated by foreign/dissimilar materials.

Where large rock is encountered, notes should be taken which would indicate:

- Average size rock encountered by percentage
- Type of rock (granite, quartz, sandstone, limestone, etc.)
- Also indicate if the material is well graded or poorly graded

While digging the area a sketch should be kept of hole location, boundaries, and topographic features (unless the area has been mapped). Care should be taken to map in all man-made features, such as pipelines, telephone, etc.

APPENDIX D: GEOMECHANICAL LOGGING

The Geomechanical Logging form is included in the back of Appendix D, it is the required rock core data sheet. The following sections describe both application of the entries of this form, as well as accepted practice for all rock core logging.

Drill Interval (From-To column)

The drill interval is the depth of where a drill run begins and ends, corresponding to the Driller's wooden blocks, which are typically placed at the beginning and end of each run. This interval is recorded under the "From-To" column.

Recovery (recovered length)

Recovery is the actual length of core retrieved from a drill run. In some cases, recovery will be less than 100 percent of the drilled interval, due to washing of fines, compaction of soft units, or the inability of the core spring (catcher) to break the stub flush with the bottom of the run. Conversely, recovery sometimes exceeds 100 percent due to some caving of the hole (re-drills), expanding clays, or removal of the entire stub at the bottom of the hole during core barrel retrieval. Inadequate and improper drilling methods which decrease the amount of core recovered should be avoided. Triple tube core barrels, which add another separate, non-rotating liner increases recovery in poor quality, semi-cemented soils, or in zones of highly variable hardness and consistency.

RQD Length (+2X core diameter)

Disregarding mechanical breaks, RQD (Rock Quality Designation) length is the sum of the lengths of the whole core pieces that are equal to or greater than twice the core diameter. Mechanical breaks are not true natural fractures, and for that reason, they are disregarded when considering RQD length, number of whole pieces, and longest-piece measurements. Mechanical breaks frequently form perpendicular to the core axis and are the result of breakage during handling or drilling.

Fracturing often occurs parallel or oblique to the axis of the core, resulting in wedge to rectangular shaped core halves. RQD length determination for these conditions should be done in the following manner: An imaginary line should be projected through the center of the core. The RQD length of an individual piece of core is defined as the distance between where this imaginary line intersects the midpoint of the structural plane bounding one end of the piece of core to a point where the line intersects the midpoint of the structural plane bounding the other end of the piece of core.

Number of Whole Pieces

Disregarding mechanical breaks, the number of whole pieces are the number of pieces that fit the criteria discussed above. No whole pieces should be counted in the “broken” or “rubbly” zones, discussed below.

The Driller’s helper should be advised to mark the location of mechanical breaks induced during extraction from the core barrel and/or transferring the material to core boxes, particularly where core lengths are broken with a hammer to fit into the box. The practice of breaking core to fit a core box should be minimized.

If there are no whole pieces in the drill run, the recovered portion is considered to be broken material, and the length of the longest piece is zero.

Length Longest Piece

Disregarding mechanical breaks, the longest whole piece of core is measured and recorded for each drill run.

Hardness (H)

Table D1 is used for the hardness field testing of each drill run. This table is the result of work by Deere [1], Terzaghi and Peck [2], Jennings and Robertson [3], and Piteau [4].

Bedding Angle

The Bedding Angle (the surface parallel to the surface of deposition) should be recorded if the bedding plane is apparent. This angle should be adjusted for the dip of the drill hole if the drill hole is not vertical.

Fracture Angle

The total number of fractures for each angle classification is measured and recorded for each drill run. The angle is measured relative to the core axis, with 90^o parallel to the axis of the core and 0^o perpendicular with the core axis.

---

[1] R1 to R5 after Deere, 1968

[2] S1 to S6 after Terzaghi and Peck, 1967

[3] Jennings and Robertson, 1969

[4] Modified by Piteau, 1970

Fracture Filling

Any fracture filling material should be noted and include secondary mineralization and clay gouge along the fractures.

Length of Whole Core

This is the sum of all whole core pieces present in the drill interval. An individual core specimen must fit one of two criteria to be considered a “whole” piece. First, as long as some component of a piece of core has a full core diameter, it should be considered a whole piece. Second, if the core is fractured down the middle (i.e., parallel to core axis), only individual pieces with lengths equal or to or greater than the core diameter should be considered whole pieces.

Length Broken Zone

A broken zone consists of a core interval composed of pieces with length of less than one core diameter in which more than 50% of the material is made up of fragments with a diameter of greater than ½ inch.

Length Rubbly Zone

A rubbly zone consists of a core interval composed of pieces with length of less than one core diameter in which more than 50% of the material is made up of fragments with a diameter of less than ½ inch.

NOTE: The combined lengths of “whole core”, “broken zone” and “rubbly zone” should equal the “recovered” core length.

ASTM D 2938

Representative samples of each rock type and variation should be tested in the laboratory in accordance with the current ASTM D 2938; the Standard Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens.

Notes

100% recovery is achievable and is required for geomechanical logging programs. All of the recovered core should be boxed and stored in accordance with the current AASHTO Manual on Subsurface Investigations.

Table D1: Relationship Between Hardness or Consistency and Unconfined Compressive Strength

Hardness	Consistency	Field Identification	Approximate Range of Unconfined Compressive Strength (psi)
		Soils and Fault Gauges	
S1	Very Soft Soil	Easily penetrated several inches by fist	< 3.5
S2	Soft Soil	Easily penetrated several inches by thumb	3.5 – 7
S3	Firm Soil	Can be penetrated several inches by thumb with moderate effort	7 - 14
S4	Stiff Soil	Readily indented by thumb but penetrated only with great effort	14 – 28
S5	Very Stiff Soil	Readily indented by thumbnail	28 – 56
S6	Hard Soil	Indented with difficulty by thumbnail	> 56
		Rock	
R0	Extremely Soft Rock	Indented by thumbnail	28 – 100
R1	Very Soft Rock	Crumbles under firm blows with point of geological pick, can be peeled by a pocket knife	100 – 1000
R2	Soft Rock	Can be peeled by a pocket knife with difficulty, specimen can be fractured with single firm blow of hammer end of geological pick	1000 – 4000
R3	Average Rock	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of hammer end of geological pick	4000 – 8000
R4	Hard Rock	Specimen required many blows of hammer end of geological pick to fracture it	8000 – 16,000
R5	Very Hard Rock	Specimen required many blows of hammer end of geological pick to fracture it	16,000 – 32,000
R6	Extremely Hard Rock	Specimen can only be chipped with geological pick	> 32,000

Project: ______ Core Size: ______ Dip: ______ Water Depth: ______ Date: ______

DDH No: ______ Total Depth: ______ Azimuth: ______ Logged By: ______ Page ______ of ______

Depth	Graphic	Geologic Description Rock Type, Alteration, Texture, etc.	Drill Run/Core Rec.			RQD		Pieces / Run	Long-Piece	Hard-ness	Bedd. Angle	Fract. Angle				Fracture Filling	Whole Core	Broken Zone	Rubbly Zone	Is (psi)
			From To	Len.	%	Len.	%					0-30	30-45	45-60	60-90					

APPENDIX E: GEOLOGIC REPORT GUIDELINES

1.0 Introduction
- 1.1 Purpose of Project
- 1.2 Location and Limits of Project
- 1.3 Site Description
- 1.4 Main Project Features
- 1.5 Purpose of Report
- 1.6 Related Reports

2.0 Subsurface Exploration

3.0 Geologic Setting
- 3.1 Regional Geology
- 3.2 Seismicity
  - Surface Fault Rupture
  - Ground Shaking
- 3.3 Site Geology
  - Fills
  - Talus
  - Colluvium
  - Alluvium
  - Bedrock
- 3.4 Discontinuities in Rock Mass
  - Bedding
  - Folds
  - Faults & Shear Zones
  - Jointing
- 3.5 Geologic Conditions Along Alignment or Area (including possibility of failure along each geologic segment)
  - Failure Types-wedge, sliding, bedding plane, topping
- 3.6 Geohydrologic Conditions
  - Surface
  - Subsurface
- 3.7 Geotechnical Engineering Properties
  - Description
  - Soil Overburden Design Parameters
  - Bedrock

4.0 Geologic Features of Engineering & construction Significance
- 4.1 Talus Slopes
- 4.2 Rock Fall Zones
- 4.3 Fault & Shear Zones

APPENDIX F: GEOTECHNICAL REPORT CHECK-LIST

1.0Title/Cover Page

- 1.1 Heading “Foundation Report” in larger letters
- 1.2 Bridge Name
- 1.3 Section Name
- 1.4 Highway and Reference Post
- 1.5 County
- 1.6 Key Number
- 1.7 Bridge Number
- 1.8 Date

2.0 Table of Contents

3.0 Detailed Vicinity Map

4.0 Body of Report

- 4.1 Introduction
    - 4.1.1 Is a project scope and purpose summarized?
    - 4.1.2 Is a concise description given for the general geologic setting & topography of the area?
- 4.2 Office Study
    - 4.2.1 Summary of pertinent records that relate to foundation design and construction
- 4.3 Subsurface Explorations and Conditions
    - 4.3.1 Is a summary of the field explorations, locations and testing given?
    - 4.3.2 Is a description of general subsurface soil and rock conditions given?
    - 4.3.3 Is the groundwater condition given>
- 4.4 Laboratory Data
    - 4.4.1 Are laboratory test results (e.g., natural moisture, Atterberg Limits) discussed and summarized in the report?
- 4.5 Summarize Hydraulics Information that affects Foundation Recommendations
    - 4.5.1 Bridge options providing required water way
    - 4.5.2 100 and 500-year scour depths and elevations
    - 4.5.3 Rip rap protection class, depth and extent
- 4.6 Seismic Analysis and Evaluation
    - 4.6.1 Bedrock acceleration coefficient and AASHTO soil profile type
    - 4.6.2 Liquefaction assessment
- 4.7 Foundation Options and Discussion
    - 4.7.1 Foundation Options and Discussion
    - 4.7.2. Pile Foundations
        - 4.7.2.1. Type (displacement/friction or end-bearing)
        - 4.7.2.2 Material specification (e.g., grade), size (e.g., o.d. & thickness) and options, open or closed-ended, tip protection

4.7.2.3 Ultimate axial capacity, est. cutoff elevation, est. tip elevation,
"est." or "order" length and minimum required tip elevation
4.7.2.4 Allowable axial capacity and factor of safety
4.7.2.5 Ultimate uplift capacities for multi-span bridges
4.7.2.6 Lateral Capacity
4.7.2.6.1 Pile group settlement
4.7.2.7 Pile group settlement
4.7.2.8 Down drag
4.7.2.8.1 How are downdrag loads to be accounted for or mitigated?
4.7.2.9 Reduced pile capacities (axial, uplift, lateral) as a result of liquefaction.
4.7.2.10 Driving Criteria and Drivability Analysis
4.7.2.10.1 Gates Equation where drivability or stress problems are not expected
4.7.2.10.2 Wave Equation for ultimate capacities greater than 545 kips or expected stress problems
4.7.2.10.2.1 The owner must have the capability to perform or be able to obtain
4.7.2.10.2.2 Wave Equation parameters provided
4.7.2.11 Is a load test recommended? Who monitors?
4.7.3 Drilled shafts
4.7.3.1 Shaft Type (i.e. end-bearing or friction)
4.7.3.2 Ultimate axial capacity provided for various diameters and lengths
4.7.3.3 Estimated settlement substantiates shaft type
4.7.3.4 Allowable axial load and factors of safety
4.7.3.5 Lateral Capacity
4.7.3.5.1 Soil Parameters for analysis (e.g. p-y data)
4.7.3.6 Is load test recommended? Who monitors?
4.7.4 Spread Footings
4.7.4.1 Ultimate bearing capacity as function of effective footing width and depth of embedment for a given settlement under allowable loads (see example)
4.7.4.2 Maximum elevation for base of footing
4.7.4.3 Description and properties of the anticipated foundation soil
4.7.5 Retaining Walls
4.7.5.1 Ultimate bearing capacity as function of effective footing width and depth of embedment for a given settlement under allowable loads (see example)
4.7.5.2 Maximum elevation for base of footing
4.7.5.3 Description and properties of the anticipated foundation soil
4.7.5.4 Global stability
4.7.5.5 Wall type options
4.7.6 Engineered Fills

4.7.6.1 Are gradation and compaction requirements provided for the engineering fill?
4.7.6.2 See example
4.7.7 Are appropriate recommendations provided for Temporary and/or Detour Structures?

4.8 Construction Recommendations
4.8.1 Pile Foundations
4.8.1.1 Minimum hammer field energy (if using Wave Equation)
4.8.1.2 Have potential obstructions (e.g. boulders) been identified?
4.8.1.3 Set period and re driving (freeze)
4.8.1.4 Pre boring required?
4.8.1.5 Jetting permitted?
4.8.1.6 Is tip protection required?
4.8.1.7 Have the effects of driving on adjacent structures been evaluated?
4.8.1.7.1 Is a preconstruction survey recommended to document existing conditions?
4.8.2 Drilled Shafts
4.8.2.1 Alternate construction methods discussed and evaluated (e.g. temporary or permanent casing)
4.8.2.2 Boulders and/or obstructions expected to be encountered?
4.8.2.3 Quality control methods (e.g. concrete integrity tests)
4.8.3 Spread Footings
4.8.3.1 Anticipated foundation material adequately described
4.8.3.2 Backfill requirements identified
4.8.4 Retaining Walls
4.8.4.1 Anticipated foundation material adequately described.
4.8.4.2 Backfill requirements identified
4.8.5 False Work Support
4.8.5.1 False work foundation type recommendations
4.8.6 Excavations
4.8.6.1 Shoring and bracing
4.8.6.2 Cofferdams
4.8.6.3 Groundwater mitigation method
4.9 Special Provisions
4.9.1 Are unique special provisions provided?
4.10 Limitations
4.11 General
4.11.1 Has the report been independently reviewed?
4.11.2 Is the report stamped, dated, and signed by a registered PE licensed to practice in Utah

5.0 Appendices
5.1 Foundation Data Sheet
5.1.1 Plan Section

5.1.1.1 Are the locations of the proposed, existing and detour structure(s) and other important shown?
5.1.1.2 Are the locations (station and offset or State Plane Coordinates of all explorations shown on the plan?
5.1.2 Profile Section
5.1.2.1 Is the ground line profile(s) shown?
5.1.2.2 Are the explorations plotted on the profile at the correct elevation and location?
5.1.2.3 Is an identification number and the completion date shown for each exploration?
5.1.2.4 Are the subsurface conditions depicted with soil and rock descriptions in conformance with UDOT Soil and Rock Classification Manual? Are the appropriate graphic symbols used?
5.1.2.5 Is the sample type shown on the profile at the correct depth?
5.1.2.6 Are SPT results ('N" values) shown on the profile?
5.1.2.7 Are the highest measured groundwater levels and the date shown on the profile?
5.1.2.8 Are percent rock core recovery, rock hardness, and RQD values shown in the summary table?
5.1.3 General
5.1.3.1 Is the presentation of the subsurface information adequately shown on the Foundation Soil Data Sheet?
5.1.3.2 Has the Foundation Soil Data Sheet been independently reviewed?
5.1.3.3 Is the Foundation Soil Data Sheet stamped, dated, and signed be a registered PE licensed to practice in Utah?
5.2 Exploration Logs
5.3 Plan and Elevation of Existing Bridge
5.4 In Situ Test Data/Results
5.5 Laboratory Test Data/Results
5.5.1 results in tabular format
5.6 Photographs
5.7 Other References as Needed

6.0 Foundation Analysis and Design Calculations Attached

7.0 The Checklist

APPENDIX G: GEOTECHNICAL REPORT GUIDELINES

1.0 General
- 1.1 Project Description
  - 1.1.1 General
  - 1.1.2 Proposed Improvements
  - 1.1.3 Climate Conditions

2.0 Previous Reports and Investigations

3.0 Existing Facilities

4.0 Findings
- 4.1 Site Conditions
- 4.2 Surface Drainage
- 4.3 Geology
- 4.4 Fault and Seismicity
- 4.5 Soil Materials
- 4.6 Geohydrologic Conditions
- 4.7 Potentially Hazardous Materials

5.0 Earthquake Considerations
- 5.1 Seismic Hazards
  - 5.1.1 Ground Shaking
  - 5.1.2 Fault Rupture
  - 5.1.3 Seismic Criteria
  - 5.1.4 Liquefaction
- 5.2 Design Criteria

6.0 Laboratory and Field Test Data

7.0 Structures
- 7.1 Description
  - 7.1.1 General
  - 7.1.2. Subsurface Conditions
  - 7.1.3 Groundwater
- 7.2 Recommendations
  - 7.2.1 Bridge Structure
    - 7.2.1.1 Foundation Design
    - 7.2.1.2 Settlements
    - 7.2.1.3 Uplift
    - 7.2.1.4 Lateral Loading
    - 7.2.1.5 Load Tests
    - 7.2.1.6 Construction Considerations
  - 7.2.2 Embankments

Vicinity Map
Site Plans
Fault Map of Vicinity Areas
Boring and CPT Location Plans
Subsurface Soil Profiles
Seismic Design Response Spectrum (5% Damping)
...Any other figures relevant to the report

Appendices
Boring Logs
CPT Logs
Laboratory Testing Data
Field Test Data (if applicable)
Instrumentation Data (if applicable)
Geotechnical Report Check List

Photographs (Append photographs of existing facilities and the new alignment to aid the presentation)

APPENDIX H: GEOTECHNICAL REPORT CONTENTS

TABLE OF CONTENTS

Show page numbers for main headings. Include list of attachments.

1.0 GENERAL

Explain the purposes of the study and scope of work.
(Note: The report is intended to aid the bidders in evaluating the requirements for excavating and supporting the ground, to assist the Contractor to plan the works, to assist the section designers and engineers in reviewing the Contractors submittal and operations, and to establish a geotechnical baseline which will serve as a basis for identification of differing conditions.)

1.1 PROJECT DESCRIPTION

This portion should include the background information which may be necessary to understand or interpret the materials and foundation report. Discussion of the suggested items may be very brief where they may have been adequately covered in a project report.

1.1.1 General

Describe existing site conditions with emphasis on site locations, existing structures and embankments, etc. Due to the size of the project and length of corridor segments, the site description should be broken down into stations, or individual structure areas.

1.1.2 Proposed Improvements

Outline proposed improvements and contiguous road system. Describe new structures, embankments, and MSE walls, etc. in this section.

1.1.3 Climatic Conditions

Include comments and effects on freeze-thaw conditions when they will be encountered and he high concentration of salt used in deicing during winters.

2.0 PREVIOUS REPORTS AND INVESTIGATIONS

Reference all pertinent reports and correspondence, properly identified. Provide a brief description of the nature of the paper if the title is not self-explanatory. It is not necessary to append material which could be normally found in UDOT headquarters files such as foundation reports by UDOT and project reports. Do append such items as materials investigations by outside consultants, etc. (i.e., materials are not available in UDOT headquarters.)

Provide a brief description of previous investigations including number of borings, depths, dates of explorations, and drilling. Include relevant subsurface conditions.

3.0 EXISTING FACILITIES

If portions of the existing highway are to be included, describe the type, age, and condition (including deflection data when available) of the structural section. If pertinent, describe cracking of pavement on embankments and pumping/failing of PCC pavement and their probable causes. Where cross streets are to be replaced in kind, describe the structural section.

Append pictures of existing facilities and the new alignment to aid the presentation.

4.0 FINDINGS

4.1 Site Conditions

A brief discussion of topography, terrains, land use, and other surface conditions affecting the highway and proposed widening. Identify sensitive surface and subsurface substructures, existing and abandoned utilities, presence of hazardous and toxic substances which could affect the overall construction of the project.

Use the UDOT alignment stations for locations.

4.2 Surface Drainage

Discuss briefly surface drainage of the site with particular emphasis on springs and signs of groundwater flow. Identify any potential surface drainage problems that may exist within the site, e.g., low areas subject to ponding and flooding, locations of nearby creeks, ponds, and rivers.

4.3 Geology

Outline the general geological formations at the project site, mention the presence of old slides, unstable areas, areas of cracking and subsidence, etc. Append any necessary topographic or geological maps, etc. and reference them in this section.

4.4 Fault and Seismicity

Mention the presence of active faults and the seismicity of the area. Append any seismic maps, seismic surveys, etc. and reference them in this section. Mention estimated mean peak ground accelerations within the study area due to previous or future MCE events. Describe types of faults and ages if applicable.

4.5 Soil Materials

Describe previous site explorations made in the project site. Outline general types of soil materials encountered in or inferred from the previous site explorations.

4.6 Geohydrologic Conditions

Describe regional geohydrologic conditions based upon previous subsurface investigations and desk studies. Include unusual groundwater conditions, springs, artesian water flow, local ponding, etc.

4.7 Potentially Hazardous Materials

Describe soil and groundwater contamination encountered during the subsurface investigation. Identify any special procedures or equipment used during drilling and handling of samples. Select Environmental Protection Agency (EPA) standard test method(s) based on site assessment of area, historical use of land, and field observations. Report results of chemical testing in tabular form. Include constituent, units of concentration, reporting limits and results. Compare concentrations of contaminants to listed values in state and federal regulations to determine severity of contamination.

5.0 EARTHQUAKE CONSIDERATIONS

5.1 Seismic Hazards

Provide discussions of seismic hazards such as ground shaking, fault rupture, seismic criteria, liquefaction potential and seismic spreading of the project site.

5.2 Design Criteria

Provide a seismic response spectrum for design of the structures on general soil types, e.g., S_1, S_2, etc. (which may have already been presented in Stage 1 Seismic Hazard Study Report).

6.0 LABORATORY AND FIELD TEST DATA

Provide a concise summary of laboratory and field testing, and the physical relationship to the plan and profile of the planned improvement. If sampling or testing is performed, in general, it should be summarized in this section as a matter of record. Items listed on the standard soils survey table include: sieve analysis, Atterberg Limits, moisture content, consolidation test, and shear strength (undrained and/or drained) data, etc. Include types of test run, results and ASTM or AASHTO designations. Laboratory results and field test data will also be summarized in the gINT logs where applicable.

7.0 STRUCTURES

7.1 Description

7.1.1 General

Describe the proposed structures to be constructed and adjoining bridges in details. These include the dimensions, types of structures number of bents, bent spacings, pier heights, types of bridge deck, etc. Include design foundation loads and pile cap elevations, if available for the new structures, types of foundation, footing or pile cap elevations of the adjoining bridges, etc. which could be referenced from as-built foundation plans.

7.1.2 Subsurface Conditions

Describe subsurface conditions underlying the structures on the basis of the new and old site investigation data. Emphasis should be made to problem soils that would cause undue total and differential settlements of the structures and instability of embankments.

Subsurface conditions should consist of a general description of the stratigraphy (using ASTM classifications). If there are significant differences between borings, describe the strata encountered in each boring. Geologic cross-sections or fence diagrams may be useful in describing subsurface relationship.

7.1.3 Groundwater

Report groundwater measured during current drilling and past subsurface investigations. Also report range of water levels in creeks and river channels. Estimate maximum rise of groundwater level, if possible in both cases. Where known, perched groundwater should also be reported.

7.2 Recommendations

7.2.1 Bridge Structures

Discuss appropriate foundation types in this section. Discuss pros and cons for the potential foundation types in this section.

7.2.1.1 Foundation Design

A. Pile Support (driven or drilled cast-in-place holes)

1. Method of support (skin friction and/or end bearing) in clays and dense sandy materials.
2. Suitable pile type(s)- reasons for choice and/or exclusion of types.
3. Pile tip elevations and length of piles.
4. Pile design load and ultimate capacity in compression.
5. Reduction of pile capacity due to negative skin friction.
6. Scour depth (elevation) if applicable and method of determination.
7. Effects of induced loads on piles due to adjoining new or existing embankments.

B. Footing Support (if applicable)

1. Elevation of bottom footing
2. Allowable and ultimate footing pressures.
3. Approximate settlements at uniformly distributed allowable loads.
4. Brief description of material on which the footing is to be placed and soil improvement, if expected (i.e., subexcavation)
5. Scour depth (elevation)

7.2.1.2 Settlements

Estimate of group settlements and time for the settlements to occur. Discuss potential differential settlements of new and/or existing pile groups due to varying subsurface conditions.

7.2.1.3 Uplift

Determine pile design load and ultimate capacity in uplift. Discuss what governs the uplift capacity and whether the weight of pile be included in calculating resistance to uplift.

7.2.1.4 Lateral Loading

Determine lateral capacity versus deformation of the pile. Discuss how pile layout, length, spacing, head-fixity and loading conditions would affect the lateral capacity of the piles. Present load-deformation analysis result summary.

7.2.1.5 Load Tests

Discuss the need for pile dynamic analyzer (PDA) tests and static load tests to verify design loads. Recommend pile load test programs for piles near abutments, bent locations if deemed appropriate.

7.2.1.6 Construction Considerations
Discuss:

1. Water table-seasonal or long term fluctuations, data for possible control in excavations (i.e. pumping, well points, tremie seals, amount of groundwater, etc.)
2. Adjacent structures-protection against damage from excavations, pile driving, dewatering, etc.
3. Pile driving - difficulties, clearance, overhead or underground utilities, other unusual conditions, etc. Discuss also effects on existing structures due to pile driving, and the corresponding mitigation measures.
4. Excavation for pile caps and footings - control of earth slopes including shoring, sheet piles, bracing, and safety considerations.
5. Need for dewatering excavations and evaluation of potential effects on surrounding area/structures.
6. Effects of induced load on piles due to adjoining new or existing embankments.
7. Corrosion effects of various soils and waters, and possibility of galvanic reaction from stray currents.

7.2.2 Embankments

Discuss where new embankments or approach fill embankments are located relative to existing structures. Describe the foundation materials on which the embankments or the approach fill embankments are founded.

7.2.2.1 Slope Stability
Conduct slope static stability analysis of the embankments and discuss the results of the analysis. Embankments without walls and not adjacent to bridges will not require seismic analysis or mitigation.

Perform dynamic analysis for the approach fill embankments without retaining walls based on the 250-year seismic event and discuss the results of the analyses. The embankments may have to be considered for dynamic analysis according to a relationship between embankment height and predicted settlement within the foundation. This relationship is shown in Figure 1 and is based upon the premise that greater foundation settlements for any given embankment height indicate increasing susceptibility to strength loss during a seismic event. Failure of approach fill embankments is acceptable unless it would damage the bridge, in which case mitigation is required.

7.2.2.2 Settlements
Estimate short term (initial) and long term (primary and secondary) settlements of the embankments and discuss the results.

7.2.2.3 Time rate of settlements
Estimate rate of settlements based upon laboratory and field data. Discuss the results.

7.2.2.4 Construction Considerations
As the construction of the embankments is controlled by the soft grounds, recommend such measures as (1) fill height limit on untreated foundation, (2) controlled rate of loading, (3) surcharging the area, (4) waiting periods, (5) use of wick drains to shorten the required time delay period, (6) slope protection, (7) use of light weight fills to reduce amount of settlement, and (8) any control devices required such as settlement platforms, piezometers, surface hubs, etc. These issues will be discussed in the following subsections on Staged Construction and Instrumentation.

7.2.2.5 Staged Construction
Discuss staged construction as a means to prevent foundation instability and the gain in undrained shear strength as a result of the staged construction. Discuss also the time required for each staged construction. The discussions should be accompanied by relevant stability analysis.

7.2.2.6 Instrumentation
Discuss where necessary the need for field instrumentation to monitor settlements including types of instrumentation, e.g., settlement platforms, settlement hubs, piezometers,... etc.

7.2.2.7 Foundation Treatments
Make specific recommendations for foundation treatments. As may be necessary, recommend wick drains, stone columns, stabilization trenches, stripping, and special treatments of original ground. Provide any additional information as required.

7.2.3 Retaining Walls and Noise Walls

7.2.3.1 Foundation Designs
Carry out global and external stability of the retaining structures (note that a check of internal stability is also needed for MSE walls); specify allowable and ultimate footing pressures. Provide a brief description of material on which the wall footing is to be founded. Recommend scour depth if footing is subject to damage by flood scour.

7.2.3.2 Settlements
Estimate total and differential settlements of the walls based on the anticipated static and seismic loadings. Briefly discuss method of estimating settlements.

7.2.3.3 Earth Pressures and Geotechnical Parameters
Recommend static earth pressures for level and sloping grounds in terms of equivalent fluid pressures, sliding resistance, adhesion mobilized along the wall base, passive earth pressures and zone, unit weight of backfill, etc.

7.2.3.4 Seismic Loading
Develop seismic earth pressures (in terms of equivalent fluid pressures) for level and sloping grounds and recommend resultant seismic forces that develop behind the wall and inertial forces from backfill (if any).

7.2.3.5 Construction Considerations
Make a provision of a drainage system behind all the walls to intercept the groundwater table. Discuss specific cut or excavation conditions within given limits. Topics which may require discussion are: types and conditions of materials, groundwater and springs, existing slopes, underground utilities, faults (if any), need for temporary support, etc. Recommend proposed cut slope design, benches if necessary for stability, maintenance, or interception of debris, temporary slope protection. Make any suggestions considered necessary for excavation procedures. Discuss select material when pertinent. Provide any additional information necessary for recommendations.

7.2.3.6 Foundation Treatments (if applicable)
Recommend types of stabilization methods to mitigate unacceptable differential settlements of the walls and to enhance wall stability.

8.0 EARTHWORK

8.1.1 Roadway and 8.1.2 Embankments

Evaluate and discuss the foundations within given limits. Items which may require discussion are: relative compaction of existing fills, groundwater, springs, unsuitable soils, expansive soils, dumps, underground utilities, etc. Use concise engineering classification in discussion of soils. A brief statement of the specific and formal reports should be included and referenced.

8.2.1 Site Preparation

Provide a brief discussion of site and sub grade preparation.

8.2.2 Fill Placement and Compaction

Recommend methods of fill placement and compaction for embankments and retaining walls in accordance with UDOT standard specifications. These may include recommendations for moisture control, fill placement over frozen soils, erosion control, contouring, temporary drainage and expansive soil. Include recommendations for special treatment which may minimize settlement or compression within the approach embankments to structures. This may include use of imported borrow, special compaction, or other methods as may be dictated by the available material. Provide additional information as may be necessary.

8.2.3 Excavation

Make a brief discussion of any permanent and temporary excavations with particular reference to soil conditions. Discuss and evaluate adverse effects (if any) as caused by the excavations on the adjacent structures and buildings.

8.2.4 Earthwork Factors

Provide earthwork factors and pertinent information for excavation and backfill.

8.2.5 Re-use of Excavated Soil Materials

Briefly discuss whether excavated soil materials can be reused or not. It may be appropriate in this section to discuss the availability or scarcity of materials; or comment on quality, economic factors, etc., which may affect the selection of material or design of section. If pertinent, comment on the disposal of material, suggested or mandatory sites, stockpiling for other sections of the project, etc.

8.2.6 Cut & Fill Slopes

Provide specific recommendations for cut and fill slopes. These may include proposed cut and fill slope design, surface erosion mitigation, control groundwater flow and springs by means of subdrains or dewatering systems.

8.2.7 Temporary Excavations

Provide specific recommendations for temporary cut and fill slopes and temporary surface erosion mitigation.

8.2.8 Dewatering and Subdrains

Recommend methods of dewatering for excavations and types of sub-drainage systems for the project.

9.0 CORROSION INVESTIGATIONS

Obtain soil samples from borings and confirm the corrosion potential of soils to material types to be used for any subsurface structure. May have to obtain additional sample in a later time when the exact structure location is known. Report test results of laboratory analysis of soil. Typical laboratory testing includes pH and minimum electrical resistivity. If electrical resistivity is less than 1,000 ohm-cm, also conduct test for sulfate, sulfides, and chloride concentrations. Use test results to determine corrosion potential of soil.

Where applicable, conduct a culvert study from the pH and electrical resistivity values to determine estimated life span for a standard gage steel culvert. Recommend a gage type to increase longevity to 50-year life span.

State that the estimated years to detrimental corrosion can vary significantly according to the factual variables of concrete manufacture that are used in construction. If there are existing structures, describe any visible evidence of distress caused by the environment. For example, the evidence of distress could be described by a simple statement such as: Concrete cracking and rust stains in substructure.

10.0 RECOMMEND MATERIAL SPECIFICATIONS

10.1 Earthwork and 10.2 Drainage Materials

Include suggested specifications for all materials used in the structural section, plus imported borrow, structure backfill, embankment fill, ballast and sub-ballast (if applicable) and drainage materials. Where possible, UDOT standards and special provisions shall be used as references. For MSE backfill, UDOT special provisions shall be used.

11.0 CLOSURE

Provide a brief closure of the report, areas of future investigation.

12.0 LIMITATIONS

List statements of limitations and potentials for unknowns.

13.0 REFERENCES

List all references cited in alphabetical orders.

LIST OF TABLES -

List all relevant and pertinent tables.

LIST OF FIGURES

List all relevant and pertinent tables. Examples are vicinity map, site plans, fault map of vicinity areas, boring and CPT location plans, subsurface soil profiles, seismic design response spectrum (5% damping), ...etc.

APPENDICES

Examples of material include boring logs, CPT logs, laboratory testing data, field test data (if applicable), instrumentation data (if applicable), copies of reports by outside consultants, seismic surveys, special correspondence or memos, maps, and cross-sections, as-built foundation drawings, etc.

PHOTOGRAPHS

Append photos of existing facilities and the new alignment.

APPENDIX I: DESIGN SOFTWARE

Geotechnical Structure Foundations Design
Unipile, L-Pile, COM624, FLPIER, Driven, GRLWEAP, QPRO, Drilled Spread Sheet

Embankment Design, Landslide Analysis
UniSettle, PCSTABL, XSTABL, STABL5M, STABL6, UTEXAS, Digitilt

Other

Geotechnical Modeling - FLAC

Rockfall - CRSP

Soil Nail Design - GoldNail

APPENDIX J: REFERENCES

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4. Bonilla, M.C., Mark, R.F., and Lienkaemper, J.J., *Statistical relations among earthquake magnitude, surface rupture length, and surface fault displacement*. Bulletin of the Seismological Society of America, v. 74, 1984, p. 2379-2411.
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8. Holloway, D. M., Audibert, J. M. E., and Dover A. R., *Recent Advances in Predicting Pile Drivability*, Tenth Annual Offshore Tech. Conf., Houston, Texas, May, 1978, pp. 1915-1922.
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